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An Investigation into the Usability of an Innovation Management Assessment Tool

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AN INVESTIGATION INTO THE USABILITY OF AN INNOVATION MANAGEMENT ASSESSMENT TOOL

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ABSTRACT

Two tools for assessing external knowledge absorption maturity were developed during Part 1 of this research based upon the work of a previous researcher. The first of these tools assesses the maturity of a single organization, or actor. The second tool assesses the maturity of the collaborative innovation network that actor is a part of. Each tool produces a maturity profile for that actor or network which can then be used to inform innovation strategy decision making.

An actor maturity assessment tool had been developed in previous research, however it did not consider how important evaluation criteria were to the individual being evaluated. To address this, a literature review was conducted to identify importance weight elicitation and score aggregation methods. The findings were then used to further develop this actor assessment tool and create a new network assessment tool. Revised Simos' method (SRF) for weight elicitation and normalization was used for determining the importance weights of evaluation criteria of actors. The Weighted Sum Model (WSM) was then used to calculate aggregate dimension scores which are used to create maturity profiles for that actor. The network assessment tool then finds the importance of those actors to their networks based on the criticality of the roles they play and their level of involvement in those roles. It was decided that the criticality of actor roles should be determined using pairwise comparison while the level of involvement an actor had in those roles could be found using point allocation. The theoretical validity and limitations of these methods were

then analyzed. Finally, the functionality of the actor tool was improved and validated through usability testing and user feedback.

After deciding that the usability concerns within the actor assessment tool were too great, the tool's development down that path was stopped. The goal of the research then shifted to identifying usability recommendations so that similarly developed decision aid tools would reach implementation. It was predicted that the lack of conciseness in the instructions of the methods developed in Part 1 of this work were significant contributors to its lack of usability. Two versions of the actor assessment tool were then developed, one which was concise and one which was non-concise. Six think-aloud studies were conducted for each tool which explored conciseness' effect on five attributes of usability: (1) efficiency, (2) effectiveness, (3) satisfaction, (4) learnability, and (5) usefulness. It was later discovered that conciseness may have an effect on non-native speaker's ability to use instructions. It was also suspected that conciseness may have an effect on perceived workload. Based on the findings from these studies a list of recommendations was made to help future academic developers of decision aid tools to better account for usability in hopes that they get to have the satisfaction of their research reaching implementation.

DEDICATION

To my parents, for bringing me into this world and allowing me the opportunity to explore it.

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I would like to thank my advisor **Dr. Summers** for creating so many opportunities for me to grow. He cemented my interest in mechanical engineering and research as early as my freshman year of undergrad when I first started working with him on the Sand Traction Creative Inquiry project. He helped convince me to further my education and gave me the flexibility I needed to truly maximize my time in graduate school. He paved the way for me to make my longtime dream of studying in France a reality as a part of my Master's at Clemson which for this I am particularly grateful.

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FOREWORD

The following report is broken into two parts: (1) development of an ACAP survey tool and (2) further investigation into its usability and usefulness. Part 1 of this work was conducted during a one-year study-abroad in France at the Grenoble Institute of Technology (GINP). The first half of this year abroad was spent completing 5 courses which were taught in either French or English, while the second was spent working on a research project and report. In addition to the successful completion of these 5 courses and research report, an intermediate foreign language proficiency exam had to be passed. I met all three of these requirements and received my industrial engineering Master's diploma from GINP in July of 2018.

It is important to note that Part 1 of this research occurred in France towards this francophone degree. As a result, the ACAP survey tool which was developed during Part 1 was written entirely in French at that time. The language used in the parts of the French version of the tool which I developed were reviewed by a native speaker to ensure accuracy. The usability studies which I conducted during Part 1 were done in French using a prepared script which had also been reviewed by a native speaker. Using the French audio recording from these sessions I was able to completely transcribe these studies with no assistance. I then translated these transcriptions into English for fuller analysis.

This tool as well as the transcripts from these studies were all translated into English before the start of Part 2. Some content from the French version of the tool had been translated into English by one of the tool's earlier developers. I used this initial translation

to verify the accuracy of my own English translation of the tool's content and my faithfulness to its original meaning, however my final translation has not been fully reviewed by an English-fluent native French speaker. Any quotes or references to parts of the survey tool developed in Part 1 are based on my own translation and interpretation of their original meaning, though care was taken not to rely on assumed meaning. Some sections of Part 1 are directly based on sections taken from my GINP report.

While conducting usability studies towards my thesis at GINP, I suspected that there were some additional usability and usefulness concerns which I simply could not fully investigate while abroad. I chose to focus on investigating these concerns further and developed my research question with that goal in mind as will be later explained. Therefore, the focus of Part 2 is no longer on the development of the ACAP survey tool specifically, but on investigating the usability and usefulness of decision aid tools when used by engineers.

PART 1:

DEVELOPMENT OF AN ABSORPTIVE CAPACITY ASSESSMENT TOOL

This work occurred while working on an industrial engineering Master's degree from GINP.

Chapter 1. Introduction to Absorptive Capacity

In order to stay competitive in an increasingly dynamic market, firms and their networks must continuously innovate by making calculated risks [1]. These risks occur every time an investment is made in future innovation which has uncertain levels of profitability [1]. Firms try to mitigate this risk of uncertainty by implementing what are known as innovation strategies [1]. One such strategy is for firms, or actors, to band together to create a Collaborative Innovation Network (CIN) [2]. The goal of a CIN is to further their competitiveness as a group by sharing complementary knowledge with other actors within their network to achieve common goals [2]. As a result, CINs must make decisions concerning their innovation strategies at both the individual actor level as well as at the network level.

This motives research to aid these decision-making processes by helping actors and their networks identify strengths and weaknesses in their handling of external knowledge which have been identified as being critical to innovation potential. External knowledge refers to the knowledge outside of individual actors - including the unshared expertise of other actors – as well as the expertise outside of the network. The ability of a firm in processing this external knowledge is known as their absorptive capacity (ACAP) [3,4]. In context of a CIN, ACAP refers to how an actor or the network as a whole (1) acquires, (2) assimilates, and then (3) applies external knowledge for the purposes of innovation [3,4]. Acquisition refers to the intensity and speed of an actor's efforts to identify and gather knowledge which is recognized as potentially useful to network objectives [3,4]. Assimilation is the process of interpreting and understanding this newly acquired

knowledge to assess its potential value and determine whether or not to apply it to network objectives [3,4]. Finally, application refers to the way an actor combines the newly acquired knowledge with prior knowledge, integrates it within their knowledge base, and then exploits this knowledge [3,4].

Each of these three classical dimensions of ACAP occur within each of three phases of contribution which result in a total of nine dimensions of ACAP as shown in Figure 1-1. The three phases are (1) the actor's *preparation* for their contribution to the network, (2) their *achievement* of that contribution, and (3) the *one-way learning* as a result of their contribution. The preparation and achievement phases both occur while the actors share a common objective and therefore involve reciprocal learning between actors. However during the one-way learning phase, the actors serve primarily themselves until the reciprocal learning phases occur again during future collaborations [5].

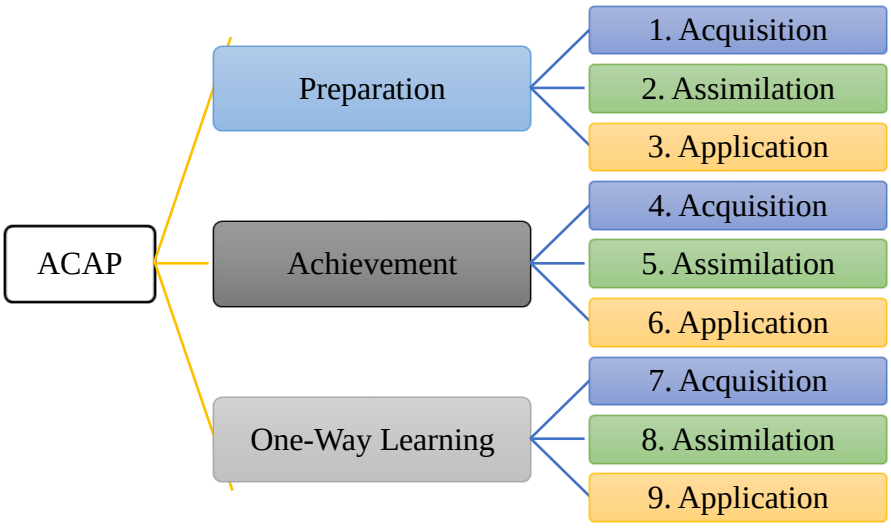


Figure 1-1. Framework of the nine dimensions of absorptive capacity

This ACAP framework was developed during the doctorate thesis of Lamiae Benhayoun as part of the Absorptive Capacity for Innovation in Companies (ACIC) project funded by ANR (*Agence Nationale de la Recherche*). This was a partnered project between the British Universities of Bradford and Liverpool, and three research laboratories from the French University of Grenoble Alpes: CERAG (*Centre d'Etudes et Recherche Appliquées à la Gestion*), G-SCOP (*Laboratoire de Grenoble pour les Sciences de Conception et d'Optimisation de la Production*), and LIG (*Laboratoire d'Informatique de Grenoble*) [5]. Benhayoun's work contributed to the first and second work packages of this project which aimed to characterize and measure ACAP within a CIN. During this work, knowledge absorption practices specific to the context of a CIN were first identified within each of nine dimensions of ACAP as shown in Figure 1-1 to characterize ACAP. Next, a maturity grid was developed to enable an actor within a CIN to assess their own ACAP. To support this, a prediction method was also developed to identify the most relevant absorption practices of an actor which will then be used to evaluate their ACAP maturity. This assessment helped to highlight the strengths and weaknesses of an actor, but not the criticality of theses weaknesses to innovation potential or success.

Part 1 of this thesis extends upon this second work package by using these evaluations of practices to produce aggregate measures of ACAP maturity of both individual actors as well as their CINs. Based on these measures, ACAP maturity profiles of actors and their CINs will be developed which can be used to identify critical ACAP dimensions and practices to inform collaborative innovation strategy decision making.

Knowledge absorption practices were evaluated based on an actor's (1) capacity and (2) willingness to do that practice when making its contribution to network objectives [5]. To maximize the potential for breakthrough innovation within a CIN, some researchers believe that there is an ideal level of similarity in capabilities among actors [6]. An actor's capabilities should be close enough in nature to the capabilities of other actors so that they are able to draw from the competencies of others as well as leverage their own competencies [6]. However, the capabilities of actors should not be so similar that there is too much overlap which might cause partners to feel the need to guard against over-sharing of information [6]. Ultimately, it is the willingness to collaborate and the *diversity* in capability of actors which is believed to be critical for innovation and is reliant upon actors not being in direct competition with their partners [6]. However, not all researchers agree. Other researchers have suggested that direct competition between collaborative actors, sometimes referred to as "coopetition," may actually increase the potential for innovation which means that lack of diversity of capability may actually have a positive effect [7]. Since the effects of diversity of capability are not clear, it was chosen to capture the effects of coopetition more directly – whether they be positive of negative – by considering capacity and willingness as separate but comparable evaluations of ACAP maturity. Separated, the disparity can be used to show the difference between the potential capabilities of an actor and their willingness to contribute which provides a more meaningful representation of the nature of the ACAP maturity of an actor.

These evaluations of capacity and willingness do help identify the strengths and weaknesses of actors, but it is not enough to fully illustrate the true ACAP maturity of an

actor or of their networks. Not all practices deemed relevant to a project's context, necessarily hold the same risk to network objectives. Similarly, actors do not have the same level of influence on the outcome of a particular project. Actors play one or more roles within their CIN to meet network objectives. For example, an actor may be responsible for project coordination or for facilitating interactions between actors within the CIN. The roles an actor plays within a CIN affect their criticality to the objectives of the network. During prior phases of the ACIC project, researchers considered the relevancy of practices to a particular project but did not assess the weight of importance of these practices to an actor or the criticality of that actor to their network [8].

These importance weights are subjective by nature and can only be cognitively understood relative to other practices or actors; they do not have inherent weights or value which can be directly determined based on objective characteristics of the project context. To produce a measure of criticality, or score, of an actor or CIN's ACAP maturity these importance weights must also be aggregated with the existing practice evaluations. To do this these practices or actors must be considered concurrently, thus a multi-criteria method for eliciting subjective weights is required in conjunction with an appropriate aggregation method. Such methods are often found within multi-criteria decision making (MCDM) methods which was where we decided to focus our initial investigation.

For Part 1 of this work, the research objective will be to develop two ACAP assessment tools which can produce meaningful maturity scores at (1) the actor level and (2) the CIN level. The research question towards this objective was the following:

RQ: How can methods from MCDM be applied to score the ACAP maturity of actors and their collaborative innovation networks?

To address this question, MCDM methods were first systematically identified from existing literature as shown in Chapter 2. The findings from this literature review were then used to select appropriate subjective weight elicitation and aggregation methods included in Chapter 3. These were then implemented to develop a model of ACAP maturity of actors and their CINs. This model was then applied to create two assessment tools to evaluate the maturities of actors and later their networks, the first of which was validated through a series of usability studies. The method SRF was used to elicit the subjective importance weight of relevant ACAP maturity practices of actors. Simple Additive Weighting (SAW) was then used to aggregate these weights with evaluations of actor maturity to produce scores which describe the ACAP maturity profile of that actor. To create network level scores the importance of actors was then elicited. To do this, the importance of role-based criteria was first evaluated using pairwise comparison. Finally, the level of involvement of actors in these roles was found more directly using point allocation. It was found that the application of SRF as a software required a lot of effort on the part of the user, however the process helped users understand concepts relating to ACAP giving them a new perspective in evaluating themselves. Users found the tool to be useful in determining actions for improving their strategies for innovation. It was also expressed that the profile representation of the results of the maturity assessment would be useful as a collaborative communication tool within their innovation teams.

Chapter 2. MCDM Literature Review

A review of MCDM literature was conducted to determine (1) an appropriate subjective weight elicitation method for the ACAP practices as well as (2) a method for aggregating these weights with their respective ACAP maturity evaluations. MCDM methods generally fall into three categories: (1) value measurement models, (2) goal, aspiration, and reference level models, or (3) outranking models [9]. In each of these cases – though their method for doing so may differ – the goal of each MCDM model is the same: to decide amongst a variety of alternatives [9]. However, the purpose of our research is more implicit than this. Our goal is not to suggest or compare specific alternative actions, but to identify practices and dimensions within ACAP where action should be considered. It remains entirely up to the DM's interpretation and discretion as to what action to take once the area is identified. For this purpose, a simply calculated score – or value – for each dimension based on the evaluations of maturity as well as the weight of importance of that practice is adequate. Such a score should communicate to the actor which dimensions of ACAP are the most critical to address relative to other dimensions. The specific importance weights of practices paired with their maturity evaluations within each dimension then provide a means of diagnosing specific weaknesses. This also gives the user better direction when deciding upon the priority of the actions they choose to take when making or improving their innovation strategies.

2.1 Weight Elicitation

Subjective weight elicitation methods are commonly found within MCDM, particularly within value measurement and outranking type models. The following subsections classify

some of these common methods based on three general approaches: (1) ranking, (2) pairwise comparison, and (3) rating. Each of these approaches has various ways that they can be implemented and each have their own advantages. There is not a single method which is most appropriate for all cases. Despite the fact that the underlying weights being elicited should be theoretically more or less the same in each approach, it is important to choose a method which is most appropriate to the particular requirements of the problem [10].

2.1.1 Ranking methods

Ranking based weight elicitation methods refer to those which require the user to put a numerical rank next to each criterion [10]. It is important to distinguish the term *ranking* within weight elicitation from the term *outranking* used within MCDM. Ranking based weight elicitation may be used within outranking type MCDM methods, however these terms are not synonymous. Outranking refers to MCDM methods which construct a binary relation which reads "alternative *a* is at least as good as alternative *b*," in other words "*a* outranks *b*" [11]. However, this is specific to the outranking of alternatives, not simply criteria as is our case.

2.1.1.1 Simos' Method and SRF

Simos' method refers to a weight elicitation and normalization method for multi-criteria situations which was originally proposed in 1990 by Jean Simos [12]. The method is most commonly used within ELECTRE-type MCDM methods. ELECTRE refers to a family of outranking methods which were originally developed by Bernard Roy in the late 1960s [13]. These MCDM all use evaluation criteria which are intrinsically weighted based

on rank. These methods have been extended in a variety of ways both for single and multi-actor decision making [14,15].

The method is considered to be well adapted to users for the purposes of eliciting subjective importance weights as it is easy, simple, and fast for them to express their preferences as an ordering of criteria. The method also has the advantage of allowing criteria to share the same rank, also referred to as being "ex aequo," and does not depend upon either the range of the scale or on the encoding of criteria to express the evaluation on this scale. This is particularly useful as users tend to prefer to express their preferences spontaneously without having a set range of the scale. The process of weight elicitation remains the same for both Simos' original and revised methods with the exception of the final step. Generalized steps for Simos' methods are summarized below:

1. Criteria are ranked from most important to least important allowing for criteria to share rank as needed
2. The minimum difference between two ranks is identified and set as equal to one unit of difference in importance
3. The difference between ranks is defined in terms of this unit of difference
4. ***Revised Simos' (SRF) method only****:* a z-factor representing how many more times important the most important criterion is compared to the least important is defined by the user

To complete these steps, Simos proposes that the DM be presented with a set of cards each corresponding to one of the criteria being considered. These criteria cards are then

grouped into same rank subsets as needed and then positioned in order of their rank of importance. The DM is then asked to consider the difference of importance between each rank and to define the smallest difference as 1 unit. The intervals between ranks are now all considered to have at least 1 unit of difference. The DM is then presented with an unlimited number of white cards each corresponding to 1 additional unit of difference between ranks. This means that if *AB* were the smallest interval it would have no white cards, an interval twice as large as this interval would have 1 white card.

The computation of the normalized weights based on this elicitation differs slightly between the original and revised methods. In the original method, the z-factor – which is user defined in the revised method – is calculated in a way which is both uncontrolled by the user as well as insufficiently founded in theory. The revised method improves upon the original method by allowing the user to control this z-factor and changing certain computing rules to strengthen its theoretical validity. This revised Simos' method is known as the Simos-Roy-Figueira (SRF) method [16].

2.1.1.2 Ratio weighting

Edwards is credited with being the first to propose ratio weighting as a subjective weight elicitation method which used within his simple multiattribute rating technique (SMART) for decision making. This elicitation is quite similar to Simos' original method, however this method chooses to set the least important criteria equal to 10 points as opposed to 1 unit. This encourages the user to use intermediate values to break ties however criteria of the same rank are not specifically forbidden. Despite this ability to be more

precise, the DM is still generally encouraged not to be too analytical with their elicitation as a gross estimation is adequate.

1. Criteria are ranked from most important to least important
2. The least important is assigned a weight of 10 points
3. Every other criterion is then assigned a weight based on their ratio of importance relative to this least important criteria
4. The ratio between each criteria weight is then verified iteratively and the number of units is adjusted as needed

The importance weights are then simply normalized by dividing each criteria's weight by the sum of all weights [17]. This method has the advantage of being algebraic, decomposed, and direct [18].

2.1.1.3 Swing Weighting

Edwards later published an alternative weight elicitation with von Winterfeldt known as the swing weighting method which he recommended for use within his a modified version of SMART which he coined as SMARTS (SMART using swings) [19]. The steps of the swing weighting method are summarized as follows:

1. All criteria are assumed to have their worst evaluations and one at a time are allowed to swing to their best evaluations
2. Criteria are ranked based on their perceived level of improvement gained from this swing
3. The criterion with the most preferred swing is given 100 points
4. The magnitudes of every other swing are given as percentages of the largest swing

Similar to the ratio weighting method, these raw weights are simply normalized by dividing each weight by the sum of all [18]. This method is unique in that it uses a theoretical worst possible alternative as its reference point for comparison of criteria rather than a unit based on the criteria themselves. Edwards defines this reference through the introduction of a scenario such as the following car buying example:

> *"[…] Imagine that there was yet another kind of car, call it the Nometer, and that you were for some strange reason required to buy it. Unfortunately, the Nometer scores 0 on all four [criteria]; it is the worst possible car. However, the somewhat kindly deity who makes the rules will allow you to improve just one of the [criteria] from its worst value to its best. Which [criterion] would you choose?"* [20]

This scenario is similarly reapplied while excluding each most preferred swing until all criteria are ranked. The DM would then apply points and calculate the normalized weights for each criterion. Using Edwards' example, true cars would then be evaluated based on these ranked criteria. The evaluations of each car would be aggregated with the weights of criteria to produce a score for each vehicle.

Unfortunately, the use of this scenario as a reference tends to be difficult for DMs to rationalize. Edwards notes that hypothetical judgments such as these can be unreliable and unrepresentative of real preferences and can also risk causing DMs unfamiliar with MCDM to lose confidence with the process [17]. It is for this reason Edwards also proposed the MCDM method known as SMARTER (SMART Exploiting Ranks) for situations where the DM cannot be relied upon. This SMARTER method uses the Rank Order Centroid approach included in the following section.

2.1.1.4 Rank Exploitation Methods: RS, RE, RR, and ROC

The rank sum (RS), rank exponent (RE), and rank reciprocal (RR) methods are by far the simplest weight elicitation methods. These rely upon the assumption that ranks are evenly spaced which means the DM does not to specify beyond the ranks themselves. However, in reality these methods should only ever be considered weight approximation techniques. The entire elicitation process is limited to the following single step:

1. Criteria are ranked from most important to least important, each criterion with its own unique rank

Such methods as these compromise on their precision and accuracy to maximize their ease of use. They are particularly useful for situations where the DM is unavailable, unable, or unwilling to be more precise with their weights. Unfortunately, these methods lack any real theoretical foundation and do not allow for criteria to be ranked at the same level which is clearly not reasonable in practice. The methods also become increasingly inappropriate

for large numbers of criteria as it becomes more difficult to straight rank [18,21]. These first three of these methods are calculated as shown in equations **(2-1**)-(2-3) below:

Rank Sum:
$$w_i = \frac{n+1-i}{\sum_{j=1}^{n} j} = \frac{2(n+1-i)}{n(n+1)}, \qquad i = 1, \dots, n \tag{2-1}$$

Rank Exponent:
$$w_i = \left(\frac{n+1-i}{\sum_{j=1}^{n} j}\right)^p = \left(\frac{2(n+1-i)}{n(n+1)}\right)^p, \qquad i = 1, \dots, n \tag{2-2}$$

where p refers to an undefined value of dispersion in the weights

Rank Reciprocal:
$$w_i = \frac{i^{-1}}{\sum_{j=1}^{n} j^{-1}}, \qquad i = 1, \dots, n \tag{2-3}$$

The fourth of these methods – rank order centroid (ROC) as shown in (2-4) – is similar to the RS, RE, and RR methods in that it only needs the DM to straight rank criteria using unique ranks, however it has been found that ROC tends to be empirically superior to its ranked-based competitors, specifically RS and RR (and presumably RE).

Rank order centroid
$$w_i = \frac{1}{n}\sum_{j=i}^{n} \frac{1}{j}, \qquad i = 1, \dots., n \tag{2-4}$$

In a simulation study where theoretical "true" weights were compared to simulated experimental values, it was found that ROC outperforms RR which outperforms RS based upon three measures of efficacy [22]. Although more effective as a calculation approach, it is important to note that ROC merely exploits the ranks and is merely intended as a weight estimation method. It is the superior of rank exploitation methods but is similarly not heavily founded in theory.

2.1.2 Pairwise Comparison Methods

Pairwise comparison is believed to the most popular weight elicitation method based on the large quantity of software available which support it compared to other methods [18]. A pairwise comparison matrix, as shown in Figure 2-1, asks the user to compare a list of elements in respect to each other element. These comparisons are then used to calculate the normalized weights of importance of the elements in question relative to other elements.

	Element 1	**Element 2**	**Element 3**
Element 1	E1 relative to E1	E1 relative to E2	E1 relative to E3
Element 2	E2 relative to E1	E2 relative to E2	E3 relative to E3
Element 3	E3 relative to E1	E3 relative to E2	E3 relative to E3

Figure 2-1. Generalized pairwise comparison matrix

Completing a pairwise comparison matrix can be particularly difficult for DMs when there is vagueness and uncertainty within the comparison. It can also be a rather exhausting process when there is a large number of elements being compared as the number of comparisons needed grows rapidly.

2.1.2.1 Original Saaty's Scale

Saaty is most well-known for his development of the Analytical Hierarchy Process (AHP) which uses pairwise comparison matrices using a fundamental scale of absolute numbers as shown in Table 2-1.

Table 2-1. Fundamental scale of absolute numbers [23]

Intensity of Importance	Definition
1	Equal Importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i
1.1-1.9	If the activities are very close

To calculate the weight of a particular element, the sum of each row in the matrix is found and then divided by the total of these sums. This scale is normally simplified to its primary rungs 1, 3, 5, and 9 however 2, 4, 6, and 8 are introduced to distinguish between two elements of similar importance. Saaty also allows for decimals if an extremely small distinction in importance is desired, particularly for large numbers of criteria.

The diagonal of the matrix compares each element to itself and thus is automatically equal to 1 using the scale above. In a consistent matrix, the values below this diagonal are merely the inverse of the values above the diagonal. Often times this lower half is automatically calculated based on the upper half for this reason, however the consistency

of the DM can be verified by having them respond to both and then measuring the inconsistency.

In AHP, pairwise comparison is used to determine the weights of elements at each level of a hierarchy. An additive aggregation method is then used to determine overall weights and/or scores based on this hierarchy. This process can be rather tedious for evaluations with many criteria or alternatives based on the increasingly large number of comparison that must be made [23]. A simple two-tier example decision hierarchy is shown in Figure 2-2.

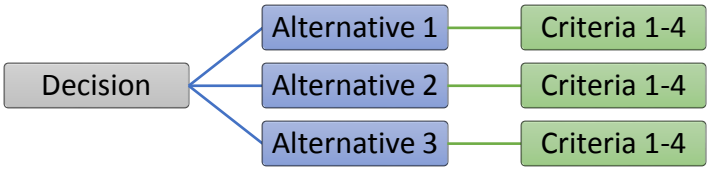


Figure 2-2. Simple two-tier example hierarchy

In this example, there are three alternatives being considered in terms of the same 4 criteria. Using strictly Saaty's AHP pairwise comparison approach, the importance of criteria would first be compared to that of every other criterion. Next, each alternative would be compared to every other alternative in terms of each criterion. In the example above, this results in one 4-by-4 matrix for the comparing criteria and four 3-by-3 matrices to compare alternatives. The number of comparisons c for a particular matrix can be calculated using equation (2-5), where n is the number of elements being compared.

$$\frac{n(n-1)}{2} = c \tag{2-5}$$

A 3-by-3 pairwise comparison matrix therefore has three comparisons whereas a 4-by-4 matrix would have 6. For our simple example, this means that a total of 18 comparisons

are needed. This number increases rapidly as the number of alternatives and/or criteria increases.

It is important to note that Saaty does customize his 9-point scale to fit the situation. For example, when using pairwise comparison to elicit perceived distances between various locations, he redefined his scale as shown in Table 2-2 allowing for DMs to indicate their preferences using letters associated to numerical values rather than using the numerical values themselves [24].

Table 2-2. Saaty's scale redefined for perceived distance problem [24]

True Value of Scale	*DM Scale*	*Meaning*
1	E	Equal Distance
3	M	Moderate Distance
5	S	Strong Distance
7	VS	Very Strong Distance
9	A	Absolute Distance
2, 4, 6, 8	B(E-M)	Between

2.1.2.2 Fuzzy Approach

Fuzzy data sets are those which are allowed to occur over a real interval so that the data avoids having sharp boundaries [25]. This approach allows data to be given with fuzziness, or with a tolerance, or vagueness which is useful for situations where only estimations of data are possible [26]. This concept has been widely applied within MCDM, in particular within the field of engineering. Fuzzy versions have been developed for many existing methods including but not limited to ELECTRE, PROMETHEE, AHP, and TOPSIS; Fuzzy is in no way limited to pairwise comparison type weight elicitations [27]. However in a two decades review of literature between the years 1994 and 2014 conducted by Mardani et al, it was found that with the exception of hybrid MCDM methods, the fuzzy approach was the most frequently published within the pairwise comparison based MCDM method known as AHP [27]. It is for this reason that we will consider the fuzzy approach the most closely within this context.

Following the fuzzy approach, the same 9-point scale as shown in Table 2-1 is used, however the descriptions of the values between one and nine are fuzzified. For example, "moderate importance" which is normally represented as a three would become "approximately moderate importance" and would actually represent an interval about three; the extremes at one and nine, however, remain as crisp numbers [28]. The size and shape of the interval around the fuzzy numbers is based on the type of fuzziness chosen, such as the Croquet's or Sugeno's fuzzy integrals. It is important to note that fuzzy inputs also result in fuzzy outputs and that the "grade of fuzziness" can be understood as a grade

of certainty. The more fuzzy the output, the more probable, or certain, it is that the true value is contained within that interval [25].

2.1.2.3 Alternative Scales

As is the case with any scale-based evaluation method, the robustness of the evaluation can only ever be as good as the appropriateness of the scale used. Some authors have challenged the original linear value scale proposed by Saaty and have developed their own scales. Ultimately, the true distribution of priority values is never truly known, thus the goal of choosing a scale is merely to choose the most appropriate based on the nature of the preferences [29].

The following examples given by Beynon [29] based on the work of Ishizaka and Labib [30], all require the DM to use the same 9 unit scale as originally presented by Saaty, however the true values of the scale differ between methods.

Table 2-3. Summary of alternative scales used for AHP

Scale Type	*Mathematical Description*	*Scale Values*
Linear (Saaty) [23,24]	$s = x$	$\{1; 2; 3; 4; 5; 6; 7; 8; 9\}$
Power [31]	$s = x^2$	$\{1; 4; 9; 16; 25; 36; 49; 64; 81\}$
Root Square [31]	$s = \sqrt{x}$	$\{1; \sqrt{2}; \sqrt{3}; 2; \sqrt{5}; \sqrt{6}; \sqrt{7}; \sqrt{8}; 3\}$
Geometric [32]	$s = 2^{x-1}$	$\{1; 2; 4; 8; 16; 32; 64; 128; 256\}$
Inverse Linear [33]	$s = \frac{9}{10 - x}$	$\{1; 1.13; 1.29; 1.5; 1.8; 2.25; 3; 4.5; 9\}$
Asymptotical [34]	$s = \tanh^{-1}\frac{\sqrt{3}(x-1)}{14}$	$\{0; 0.12; 0.24; 0.36; 0.46; 0.55; 0.63; 0.7; 0.$
Logarithmic [35]	$s = \log_2(x + 1)$	$\{1; 1.58; 2; 2.2; 2.58; 2.81; 3; 3.17; 3.32\}$

It is important to note that these scales are clearly not mathematically equivalent and would result in different preference distributions despite having the same initial input from the DM. For our case, the shape and location of the distribution of preferences is non-

critical as our numerical results are only meaningful compared to other similarly calculated values. It is for this reason that although these alternative scales were considered, for our situation it is reasonable to simply use Saaty's original linear scale. We acknowledge that we are not certain if the preferences of users are truly linear or not, however we choose to make this assumption.

2.1.3 Point Allocation and Rating Methods

The following methods include those where a numerical weight is elicited directly from the DM. Although simple arithmetic can be used to translate one into the other, the weighting behavior of the DM between these methods is fundamentally different; it is important to remember that these are not equivalent methods [36].

2.1.3.1 Budget (or Fixed) Point Allocation

Budget point allocation, sometimes referred to as fixed point allocation, forces the DM to give relative weights of criteria by making trade-offs between their importance weights. Following the method, the user is asked to distribute a predefined budget of points – usually 100 points as it is easiest to normalize – amongst a list of criteria. In doing so, the DM is only able to give a higher importance to a criterion by lowering the importance of another. This method does allow for criteria to have the same weight if the DM chooses. Distributing points can be a mentally difficult task for the DM to do directly as it is difficult to associate a numerical value to one's preferences [18].

2.1.3.2 Direct Rating (Likert)

The direct rating technical is aptly named as the DM directly weights a list criterion using a Likert-like numerical scale – usually 1-5, 1-7, or 1-10 – based on strength of

importance. There are no tradeoffs between criteria and the user is not forced to compare criteria strengths in any way [18].

2.1.3.3 Graphical Rating

There are many versions of graphical rating, all of which will not be considered here, however the general process remains the same for all. A measurement line is offered to the DM which ranges from low to high importance. The DM must then mark on the line where they believe their preference falls. This can be either a shared line for all criteria which encourages the user to compare criteria, or an independent line for each criterion where each is evaluated independently though the user may iteratively verify their ratios at the end. A shared line encourages the user to indicate weights somewhat relative to other criteria however it can become cumbersome when there are many criteria. Using independent lines for each criterion is much easier to do, however the user is in no way forced to consider relative importance of criteria. This method is often criticized for allowing the DM to be too carefree in their assignment of weights without consideration of its implications [18]. The weights are then normalized based on the length of the line. Two example representations of graphical rating for a set of three criteria are shown in Figure 2-3.

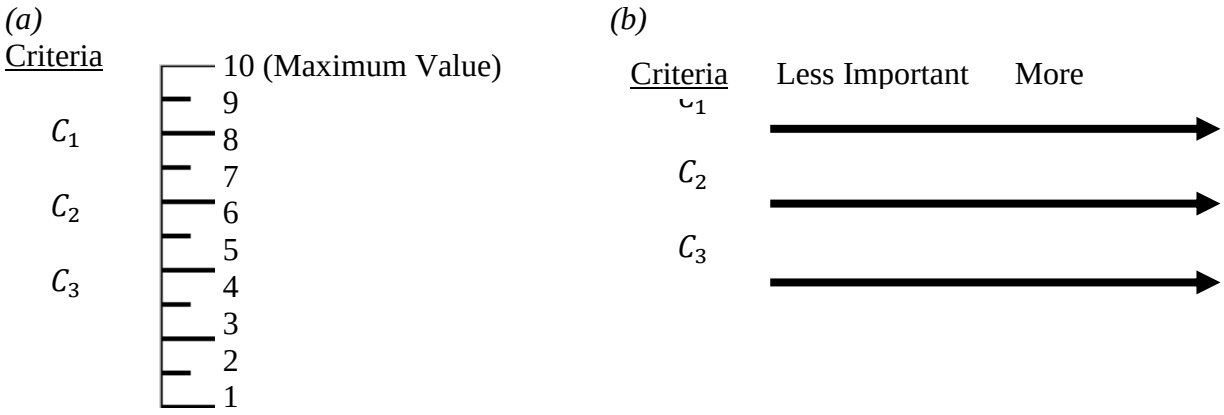


Figure 2-3. Examples of graphical rating, (a) numbered, shared line style reproduced from [10] **and (b) unnumbered, independent line style reproduced from** [18]

2.2 Aggregation Methods

After eliciting weights, it is necessary to determine an appropriate multicriteria aggregation procedure (MCAP). MCAP methods are used to attach importance parameters to criteria evaluations. Our goal of using MCAP is to determine a weighted score which considers both the importance of a list of practices as well their ACAP maturity. These scores are intended to be used to produce an implicit representation of an actor or network's ACAP which can be interpreted to make innovation strategy decision making. Thus, it is not required that the scores have explicit, stand-alone meaning. It is for this reason we choose to focus on the two simplest methods.

2.2.1 Weighted Sum Model

The weighted sum model (WSM), sometimes referred to as simple additive weighting (SAW), uses the formula shown in equation (2-6) where w_i refers to the relative weight of the criteria, x_i refers to the score of criteria, and A_j refers to the calculated aggregate score.

$$A_j = \sum w_i x_{ij} \quad \textbf{(2-6)}$$

It is important to note that A_j normally refers to the aggregate score of an alternative which would be evaluated based on the same criteria. This approach is completely compensatory which means that its accuracy is heavily reliant upon the encoding of criteria. This method has the advantage of being very simple to implement and is widely used, in particular for AHP, for this reason despite its weakness.

Encoding of criteria refers to the nature of the scale that is used for evaluation. For example, when deciding among a list of alternative cars to purchase, the price of the car as a criterion may be extremely important to the decision. However, if the prices of all cars only range between 15,000 and 15,100 then the increase or decrease in price may not be important [20]. In a unidimensional problem where all criteria are measured in the same units, such as dollars, this does not pose a problem. However, if the cars are also being compared based on a criterion of a different unit – such as comfort level – the range in comfort levels between vehicles may be significant even when the criteria itself is not the priority. It therefore becomes difficult to evaluate price the same way one evaluates comfort level to create a meaningful score. It is for this reason that the weighted sum model is only truly appropriate for single dimensional problems where there are no changes in the units of evaluation among criteria [37].

2.2.2 Weighted Product Method

The weighted product method (WPM) multiplies a series of ratios for each criterion which is then raised to the power equivalent to the relative weight of that respective criterion as shown in equation (2-7) below where a is the evaluation of a criterion, w is the

relative weight of that criterion, and $R\left(\frac{A_k}{A_l}\right)$ is the ratio of preference between two alternatives.

$$R\left(\frac{A_k}{A_l}\right) = \prod_{j=1}^{n}\left(\frac{a_{kj}}{a_{lj}}\right)^{w_j} \quad \textbf{(2-7)}$$

This method produces a list of ratios for each alternative relative to other alternatives. These ratios can then be used to create a ranked list of alternatives.

Alternatively, if a performance value – or score – is desired, the formula can be modified as shown in equation (2-8) [37,38].

$$P(A_k) = \prod_{j=1}^{n}\left(a_{kj}\right)^{w_j} \quad \textbf{(2-8)}$$

The weighted product method differs from the additive model in that it tends to over-value the extremes. This means that criterion far from the average are considerably favored or unfavored within the final score.

Chapter 3. Research Method

Comparison criteria were identified in literature and used to select the most appropriate of these reviewed methods for further development. A model was then proposed and analyzed to understand its limitations. This model was then used to further develop the actor-level ACAP assessment tool as well as create a network tool. The functionality of the tool was then validated through multiple iterations of usability studies. This research methodology is summarized in Figure 3-1.

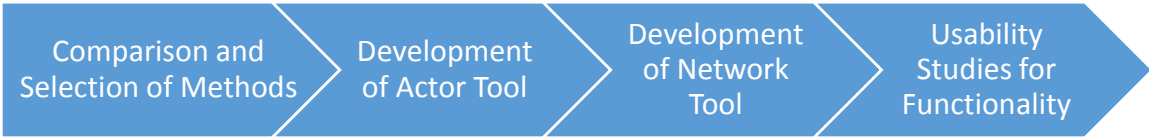


Figure 3-1. Summary of research methodology

It is important to emphasize that we are only doing the initial steps of MCDM and are merely eliciting subjective weights of lists of criteria; we are not deciding between alternative actions or solutions. This means that there are some criteria of MCDM which are not applicable to our case. The criteria we have thus chosen to consider as well as an explanation for the irrelevancy of certain other criteria normally considered within MCDM will be further explained in the following sections.

3.1 Selection of Method

Our research objective is to extract methods from MCDM literature which can be used to produce an informative ACAP maturity profile for both actors as well as their networks. This is a two-part problem which will be addressed by calculating weighted ACAP dimension scores for actors and their CINs as summarized in Figure 3-2.

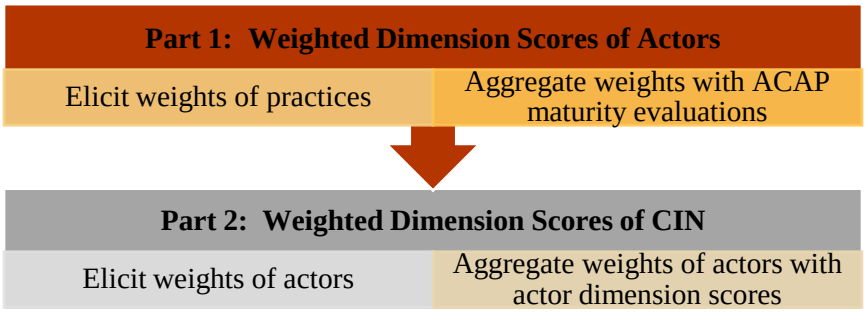


Figure 3-2. Summary of problem

3.1.1 Comparison of Weight Elicitation Methods

Weighting methods are used in the majority of multi-criteria decision making (MCDM) models [39]. The objective of weight elicitation is to define a meaning to importance and provide a means a DM to communicate that importance in a meaningful way. Ranking, rating, and pairwise comparison methods for weighting criteria have been compared in the past and it has been found that there was no significant difference in the results between these methods [10]. However, each method does differs in terms of accuracy, ease of use, complexity for users, and theoretical foundations and should be chosen specific to the problem at hand to optimize these comparison criteria [18]. These four criteria and their definitions from literature are summarized in Table 3-1.

The *accuracy* of the methods is what instills confidence in the results of using our proposed method and makes the tool which we are developing using the model more likely to be adopted by industry. Furthermore, if the method has reasonably high accuracy and any lack of robustness can be well controlled and understood, it will allow us more opportunities to expand upon this research in the future.

It is also important to consider that within each of the nine dimensions of ACAP the maximum number of practices ranges between 5 and 14 with a grand total of 76

practices across all dimensions which greatly effects the *ease of use* of the tool. These practices in both French and English are included in Appendix A for reference. Each of these practices also has two criteria types associated to them which results in a total maximum number of evaluations of 152, even before eliciting the subjective weights of each of these 76 practices. Before usability testing, it was thought that the process of evaluating ACAP without considering the weights of practices took approximately 1 hour. Based on previous conversations with members of existing CINs, it was believed that the entire scoring process – including the process of importance elicitation – should at maximum take no more than 2 hours for a single actor to evaluate themselves. No specific time estimate was decided for the CIN scoring process, however our goal was to similarly minimize this time needed as much as reasonably possible. These targets will be considered in our comparison of the *ease of use* of each method which will be measured in terms of how quickly the tasks needed can be completed.

It should be noted that we intend to apply this model within a software application which will be used by PMEs at CINs in France. As such, ensuring *simplicity for users* was a particularly important criterion to consider in choosing our method. The end users of the assessment tool cannot be expected to have any familiarity with the concepts of ACAP or with any of the processes used to elicit subjective weights. It is also not expected that there will be someone available to train users on how to use the tool, therefore if the tool is too complicated and cannot be figured out by itself, it is more than likely that the tool will simply not be used at all which provides no benefit to our immediate end-user. Although our academic purpose is the development and validation of a model for eliciting subjective

weights which can completed regardless of whether the tool is ever used by industry or not, the satisfaction of our clients in the application of this model is critical for maintaining our industrial partnerships for continuation of this research as well as future research goals.

Our final criterion is the *theoretical foundation* of the method. This criterion shares responsibility for increasing the confidence of users in the results of using our proposed method. Regardless of accuracy, if the theoretical foundation of the method itself will not be trusted.

Table 3-1. Comparison criteria for weight elicitation methods

Criteria	Definition and Scale
Accuracy	Accuracy refers to how well the measured weights reflect the true weights. This is generally based on the rationale of the method [18]. Accuracy ranges from HIGH to LOW, high meaning that the true and measured weights are very close and low meaning that these weights are not.
Ease (Speed) of use	Ease of use is often at the cost of accuracy and is based on the quickness of which they can be used [18]. This is critical as many DMs do not have adequate time for some more complex (though maybe more accurate) approaches [40]. Ease of use ranges from HIGH to LOW, high meaning that the method is quick to use and low meaning that it is very time consuming to use.
Simplicity for users	An items importance is cognitively understood as informal natural language rather than quantitatively [27,41]. If a method is too complex, a lack of understanding of the method and resultant weights will often result in the model being misused [42]. Simplicity for users ranges from HIGH to LOW, high meaning that the method is easy to understand and low meaning that it is complex and prone to being misused.
Theoretical foundations	Attention must be given to not oversimplify the extraction, the experimental calculated weight must well represent the theoretical true weight. It is best to be direct and simple for understanding but without compromising the underlying theoretical validity [38]. Theoretical foundations ranges from HIGH to LOW, high meaning that the method is well founded in theory and low meaning that the method is unfounded or poorly founded.

From the review of MCDM literature included is Chapter 2, we compared 10 different methods falling within three categories as shown in Table 3-2. These comparisons will then be contextualized for each of the two parts of our problem as outlined in Figure 3-2 to select the appropriate methods.

Table 3-2. Comparison of Weight Elicitation Methods

		Accuracy	*Ease (Speed) of Use*	*Simplicity for Users*	*Theoretical Foundation*
Ranking Methods	*Simos' Method and SRF*	**High** Criteria ranked relative to other criteria, relative difference between each rank given	**Medium** 4 direct steps	**Medium** Ranking is intuitively simple, however difference between ranks and z-factor adds complexity	**High** Considered well adapted to users [16]
	Ratio Weighting	**Medium** Criteria ranked relative to other criteria, each rank compared only to least important rank	**Medium** 4 direct steps	**Medium** Ranking is intuitively simple, however defining ratio adds complexity	**Medium** Decomposed and direct [18]
	Swing Weighting	**Medium** Criteria ranked relative to other criteria, each rank compared only to most important rank	**Medium** 4 direct steps	**Low** Ranking is based on worst case scenarios which is complex to ponder, defining swing percentage adds complexity	**Low** Relies upon hypothetical judgments [17]
	Rank Exploitation	**Low** Criteria ranked relative to other criteria only, no shared rank	**High** 1 direct step	**High** Ranking is intuitively simple	**Low** Weight estimation method only [18]

Table continued…

		Accuracy	*Ease (Speed) of Use*	*Simplicity for Users*	*Theoretical Foundation*
Pairwise Comparison	*Saaty's Scale*	**High** Criteria compared relative to every other criteria	**Low** Many comparisons needed, unreasonable for large numbers of criteria	**High** Scale can be customized to be simple to use	**Medium** Most popular method, some concerns with constraining user inputs to a scale [18]
	Fuzzy	**High** Criteria compared relative to every other criterion	**Low** Many comparisons needed, unreasonable for large numbers of criteria	**High** Scale can be customized to be simple to use	**High** Interval more likely to capture true value [25]
	Alternative	**High** Criteria compared relative to every other criteria	**Low** Many comparisons needed, unreasonable for large numbers of criteria	**High** Scale can be customized to be simple to use	**Medium** Requires better understanding of preference distribution [29]
Point Allocation and Rating	*Budget (Fixed) Point Allocation*	**Medium** Relative tradeoffs considered	**Medium** Direct method but with tradeoff consideration	**Medium** Mentally difficult to associate numerical value to preference, complex to consider tradeoffs	**Low** Weighing behavior has been shown to deviate from ideal [36]
	Direct Rating	**Low** Not necessarily relative	**High** Direct method	**High** Low cognitive processing required	**Low** Users tend to be biased around a specific region of a scale [36]
	Graphical Rating	**Low** Not necessarily relative	**High** Direct method	**High** Low cognitive processing required	**Low** Users tend to be biased around a specific region of a scale [36]

The most accurate methods were those which require to DM to give the weights of criteria relative to other criteria; the highest of these being the ranking method SRF and the pairwise comparison methods. The ease of use differed between methods based on the quantity and speed of operations needed for the elicitation. The easiest methods were those which were most direct – namely the rank exploitation, direct rating, and graphical rating methods. The simplicity for users was the most effected by the intuitiveness of the method as well as how cognitively similar the elicitation process was to how DMs truly perceive preferences. Again, rank exploitation, direct rating, and graphical rating stand out as simple methods, however the pairwise comparison methods were also rated high due its use of a linguistic comparison scale. Finally, the theoretical foundation of the method was based on critiques of the methods found in literature as well as their popularity. The strongest of these was the SRF method which was specifically designed to be well adapted to the user while not compromising on its accuracy. Also notable was the fuzzy pairwise comparison method as it allows the DM to give preferences with fuzzy integrals rather than crisp numbers which better captures the uncertainty of subjective preferences.

Following the decomposition of our problem shown in Figure 3-2, we will now compare these methods in terms of each of the two parts of our problem: (1) weighted dimension scores of actors and (2) weighted dimension scores of the CIN.

3.1.1.1 Weighted Dimension Scores of Actors: SRF

Considering this, for the weight elicitation of practices needed for calculating ACAP maturity scores of actors, it was decided to use the SRF method. A close runner up was the pairwise comparison methods, however the pairwise comparison method can

become very exhaustive for large numbers of criteria as is the case when weighting ACAP practices. The maximum number of criteria for each dimension of ACAP ranges from 5 to 14 practices. Following equation (2-5), this means that the maximum number of comparisons needed to complete just the upper half of a pairwise comparison matrix ranges from 10 to 91 comparisons per dimension. SRF by comparison only requires at most 5 to 14 practices to be ranked. If each practice is given a unique rank this would result in a maximum of 4 to 13 intervals to be weighted. Finally, a single z-factor must be defined for each dimension. This results in a grand total of only 10 to 28 operations per dimension at maximum.

3.1.1.2 Weighted Dimensions Scores of CIN: Pairwise Comparison and Point Allocation

For the scores of the CIN, it is the weights of the actors themselves which are needed. To avoid bias caused by having actors determining their own importance, we choose to introduce a two-level hierarchy within this elicitation such as is standard practice within AHP. It is believed that this hierarchy will present actor importance in a way which will allow a group of experts from those actors to still come to a consensus on actor importance [23,43]. The first level of the hierarchy will have a group of experts weight the importance of CIN roles to network objectives. These role based criteria that were introduced will be further explained in §3.2.6. The second level then asks this group of experts to distribute weight to each actor based on that actor's involvement in each of these roles. The model will then calculate true actor importance weights.

For just the first level, it was decided to use pairwise comparison. The first reason for this was due to low number of role based criteria – only 6. Following equation (2-5),

only 15 comparisons are needed for pairwise comparison to provide a results believed to have strong accuracy which is believed not to be exceptionally tedious. The second reason is that the process of weighting actors is intended to be done by a group of experts. Pairwise comparison has the advantage of being very systematic and structured, maximizing the simplicity for the user which is particularly critical in a group setting. The goal is for the focus to be on discussing the importance of roles, not on how to properly use the tool. The specific pairwise comparison scale that was chosen and why will be further explained in §3.1.1.2.

For the second level which weights actors based on their involvement in these role criteria, it is believed that a more direct weight elicitation method is ideal. For this reason, point allocation was chosen. Point allocation is simple to understand which is particularly necessary for a group decision making setting. This method does require numerical values to be directly applied which can be cognitively difficult for DMs in certain scenarios, however it is believed that level of involvement will be relatively intuitive for a group of experts to apply a percentage to. Compared to the other direct methods – specifically direct weighting, graphical rating, and rank exploitation – which may be slightly easier to use, point allocation is believed to optimize the need for simplicity without over-compromising on accuracy. Point allocation has the unique advantage of requiring the user to consider tradeoffs which forces the DM to give truly relative weights while still allowing actors to share the same weight as needed.

3.1.2 Comparison of Aggregation Methods

The validity of the aggregation method is heaving reliant upon the nature of the criteria and how they are being evaluated. The first consideration is the effects of compensation between criteria. Criteria are considered compensatory if strong criteria are able to make up for – or compensate for – the weaknesses within other criteria [44]. This means that there exists an interrelatedness between criteria which is nontrivial to the preferences of alternatives. For example, when choosing what car to buy it is impossible to evaluate price the same way that you might evaluate a cars comfort, safety, and power levels. Although having a comfortable, safe, and powerful car is certainly important, there are limitations to your willingness to compensate on price level to maximize the other three criteria. This would be an example of a non-compensatory problem.

We acknowledge that some non-compensatory effects may exist within our ACAP criteria, however it is reasonable to ignore these effects as they are believed to be minimal. Part of the reason for this is the way our evaluation is encoded. The scores for capacity and willingness are always kept separate – these scores are never aggregated together. Each is evaluated using its own simple 4-point scale which is universal across all criteria. It is therefore reasonable to assume that an aggregate evaluation of capacity – or willingness – can be found through a simple aggregation of its weighted values. This is because the evaluations remain single dimensional meaning that there are no changes to the units of evaluation among criteria. Since the units never change, it can also be reasonably assumed that criteria are able to compensate for one another within each evaluation type. The 4-point scales used for each were also shown to be directly comparable within Benhayoun's

thesis which is why we are still able to compare the scores calculated based on these evaluations even if it is not reasonable to aggregate these together [5].

However, it is important to note that although the practices within each dimension are always evaluated based on capacity and willingness, the specific practices evaluated are neither universal to all dimensions nor universal to all actors. Although both capacity and willingness remain relevant to all dimensions and all actors, the specific practices for evaluating these changes based on context. This does pose a robustness concern when comparing scores between dimensions and particularly between actors. This also prevents us from producing a meaningful aggregate score across dimensions though this is not of interest to us. The objective of producing aggregate dimension scores for actors and their networks is to produce implicit profile representations of their respective ACAP maturities. The scores themselves do not have explicit meanings by themselves nor do we intend on them being used in this way. A scale of good and bad scores cannot be universally defined as it would change based on context of the project and the CIN, however by comparing scores between dimensions and between actors within a certain project at a certain time, DMs can gain insight into the relative ACAP maturities of actors and their CINs.

3.1.2.1 Aggregation Within Actor and CIN Scores: WSM

This leaves us with two simple options for aggregating scores within each dimension of ACAP both at the actor and CIN levels: WSM or WPM. The principal of both methods is the same, however the distribution of scores changes between the two methods. Using the additive approach, scores are directly representative of the evaluations and weights they aggregate. The DM can easily understand how these scores were calculated even without

seeing an explanation of the formulas involved and can easily understand how changes to their auto-evaluations effect the results. Alternatively, the multiplicative approach forces the highest and lowest scores to the extremes making strengths and weaknesses more apparent, however this is at the cost of loss of intuitive understanding in how these values were calculated by the DM. We therefore choose to use WSM which has been found to be the default for many MCDM methods, including AHP [23,37].

We acknowledge that some authors have taken issue with the way WSM has been historically implemented within MCDM – particularly within the pairwise comparison process of AHP – due to the incomparable encoding of criteria as well as problems concerning compensatory effects [16,44,45]. As previously discussed, our separation of capacity and willingness keeps our scores for capacity and willingness of each dimension unidimensional which is why the use of WSM to aggregate these relative weights and their evaluations remains acceptable in our case.

3.2 Explanation of Proposed Model

The proposed model for eliciting and calculating ACAP maturity scores is summarized in Table 3-3.

Table 3-3. Proposed Model

	Step	*Method*
Actor Level Scores	Relevancy of ACAP Practices	6-point Likert scale (existing method)
	Weight Elicitation of ACAP Practices	SRF
	Evaluation of Capacity and Willingness of ACAP Practices	4-point Likert scales (existing method)
	Aggregation of Weights and Evaluations of ACAP Maturity	WSM
CIN Level Scores	Weight Elicitation of Role Criteria	Pairwise Comparison
	Weight Elicitation of Involvement of Actors	Point Allocation
	Aggregation of Weights and Actor Scores	WSM

The first and third steps of the proposed model were developed and validated in Benhayoun's thesis [5]. These will be described here to validate their applicability to our proposed method, however for full validation please refer to her original work.

The following sections will illustrate the proposed model for calculating ACAP maturity scores for both individual actors and the network as a whole through an example. This example will be used to explain the model's validity and limitations.

3.2.1 Relevancy of ACAP Practices

During Benhayoun's thesis, an extensive literature review was conducted which produced a list of criteria which captured the context of the project being evaluated. These criteria contextualize the project by gauging five topics: (1) what is the nature of the external environment of the actor, (2) what role does external knowledge play in the project, (3) what role does the actor play within the project, (4) what are the motivations of

the actor for participating in the project, and (5) how does the actor compare to other actors involved in the project. Criteria within these topics are posed to the DM as statements; the DM then indicated their level of agreement using a simple 6-point Likert scale. ACAP maturity practices are then assigned a relevancy score calculated based on the responses to this context survey. A practice is only considered relevant if it has a relevancy score over a certain threshold value. Though this threshold remains the same for all practices, there is not a universal calculation for practice relevancy. In this way, indicating high agreement for a particular context criterion may cause some practices to become more or less relevant while others may not be affected at all. The details and validation of this method of calculating relevancy is further explained in Benhayoun's thesis [5].

The practices below the relevancy threshold are now omitted from further analysis. This practice of omitting particularly unimportant criteria which are always expected to receive low weight has also been done within MCDM such as Edwards SMARTS and SMARTER methods [20].

As context is unique to an actor and their project which practices are considered relevant changes between actors and between projects. This means that actors are not evaluated based on the same criteria. Though this does pose a robustness concern, it is necessary due to the way the model will eventually be applied. This will be further explained in §3.2

3.2.2 Weight Elicitation of ACAP Practices

Following the steps for SRF explained in §2.1.1, the normalized weights of a list of criteria are calculated based on the elicited rank, the relative size of the interval between

ranks, and relative importance of the most important compared to the least important criteria. In our case, the criteria being evaluated are the list of relevant practices previously identified. Each practice actually corresponds to two criteria: one being the capability of an actor to perform that practice and the other the willingness. However, since the importance of both criteria within each practice is theoretically the same, we choose to weight the practice directly and use this as the criteria weight for both during our score aggregation.

The implementation of SRF will now be illustrated through an example using 8 criteria as shown in Table 3-4, each rank corresponding to a unique criterion. Notice that some criteria are allowed to share the same rank, that ranks are required to be consecutive, and that a rank of 1 is considered the most important. In this example, the DM has chosen to use 5 ranks which produces 4 intervals between ranks.

Next, the DM has identified the interval between ranks 2 & 3 (and consequently 3 & 4) as the smallest interval of difference. These smallest interval(s) are – by necessity of the method – defined as one unit of difference. The DM then indicates the size of the other intervals using this unit.

Finally, the DM indicates a factor z, how many more times the highest ranked criteria is compared to the lowest ranking criteria.

Table 3-4. Example SRF data

Elicited Ranks	*Resultant Intervals*	*Relative Size of Interval*	*z*
1	1 & 2	2	10
2	2 & 3	1	
3	3 & 4	1	
4	4 & 5	4	
4			
4			
5			
5			

This does differ slightly from true SRF however we will prove that our proposed implementation of the method is mathematically equivalent. In the original SRF method (aka. Revised Simos' method), the DM is similarly asked to identify the smallest interval and define it in their mind as 1 unit. However, instead of having the DM directly indicate how many units of difference are on each interval as we have chosen to do, in the original SRF method the DM is asked to indicate how many *more* units of difference are on every other interval. This means that the values the DM indicates in our proposed method are all one unit above the values that would be normally indicated in the original SRF. Thus, our calculations can and must be easily adjusted accordingly to remain equivalent.

Phrasing the elicitation as *how many more units*, as is normally done in SRF, is supposedly well adapted to the DM when physical criteria cards and white, interval-difference cards are being used, however using physical cards was not a viable option for our application as will be discussed further in §3.2. In an effort to help the DM better understand how a unit of difference was defined, we chose to have the DM simply indicate *how many units* of difference were on each interval. The correct usage and understanding of the definition of a unit is critical to the theoretical validity of the SRF method. A few

alternative methods for having the user define this unit were considered, as shown in Appendix C, however only one maintained the same level of control over the DM without being over-constraining.

Once the elicitation is finished, these values are used to calculate normalized values for criteria. Following the SRF approach of Figueira et al, the inverse ranks are first found [16]. Next, the number of units of difference directly following each rank e_r is calculated based on the number of white cards directly following each rank e_r' where r refers to the index of the rank. However, for our implementation approach e_r was elicited directly so this calculation is not necessary. The relationship between these values is summarized in equation (3-1) for reference. The change to this calculation is one of two mathematical changes to the original SRF method that was made for our implementation approach.

$$e_r = e_r' + 1 \tag{3-1}$$

The total number of units of difference e is then calculated using equation (3-2) where n is the number of criteria being considered.

$$e = \sum_{r=1}^{n-1} e_r \tag{3-2}$$

Next, a coefficient u is calculated using equation (3-3). This value is rounded to 6 decimal points as needed.

$$u = \frac{z-1}{e} \tag{3-3}$$

The non-normalized weights $k(r)$ are now calculated using equation (3-4) with $e_0 = 0$.

$$k(r) = 1 + u(e_0 + \cdots + e_{r-1}) \quad \textbf{(3-4)}$$

Finally, the unrounded normalized weight k_i^* can now be found. For a criterion g_i of rank r and weight k_i' where $k_i' = k(r)$ equations (3-5) and (3-6) are first used.

$$K' = \sum_{i=1}^{n} k_i' \quad (3\text{-}5)$$

$$k_i^* = \frac{1}{K'} k_i' \quad (3\text{-}6)$$

At this point we introduce our second mathematical deviation from the original SRF method. In the original method the value of k_i^* would now be optimally rounded based on comparisons of two ratios of dysfunction, one for when the value is rounded upwards and the other downwards. We choose to omit these optimal rounding steps and to instead simply round k_i^* to 6 decimals places. This rounded normalized weight is referred to as k_i.

The choice to omit these additional rounding steps was done because of their lack of robustness in handling same-ranking criteria. Following the original method, criteria are ordered based on each ratio of dysfunction. The ratios are then compared to determine how each k_i^* should be adjusted so that their rounded sum is always 1. However, for situations with same ranking criteria, which of these criteria will be adjusted is arbitrarily selected causing same-ranking criteria to have slightly different weights. Based on the subjective nature of importance within our criteria, we expect there to be many scenarios which have same-ranking criteria therefore this rounding optimization process holds little added benefit. Other authors have also noted that if enough decimals are chosen and if the number of criteria is relatively small, the error introduced by rounding off decimals is already negligible and thus there is no need to optimize it [46]. It is for this reason we chose to

keep 6 decimals points of k_i^* for our rounded normalized weight values k_i. The results of these calculations using our example data from Table 3-4 are shown in Table 3-5.

Table 3-5. Example normalized elicited weights using SRF

i	*Elicited Ranks*	*Inverted Ranks*	e_r	k_i'	k_i	
1	1	5	-	10	0.316206	$z = 10$
2	2	4	4	5.5	0.173913	$e = 8$
3	3	3	1	4.375	0.138340	$u = 1.125$
4	4	2	1	3.25	0.102767	
5	4	2	-	3.25	0.102767	
6	4	2	-	3.25	0.102767	
7	5	1	2	1	0.031621	
8	5	1	-	1	0.031621	
		SUM	8			

3.2.3 Evaluation of Capacity and Willingness of ACAP Practices

From the work of Benhayoun, a 4-point Likert scale is then used to evaluate the maturity of actors in their performance of relevant ACAP practices. This scale was defined using linguistic terms specific to each of the two criteria types: capacity and willingness. This scale is summarized in Figure 3-3 from page 35 of Benhayoun's thesis [5].

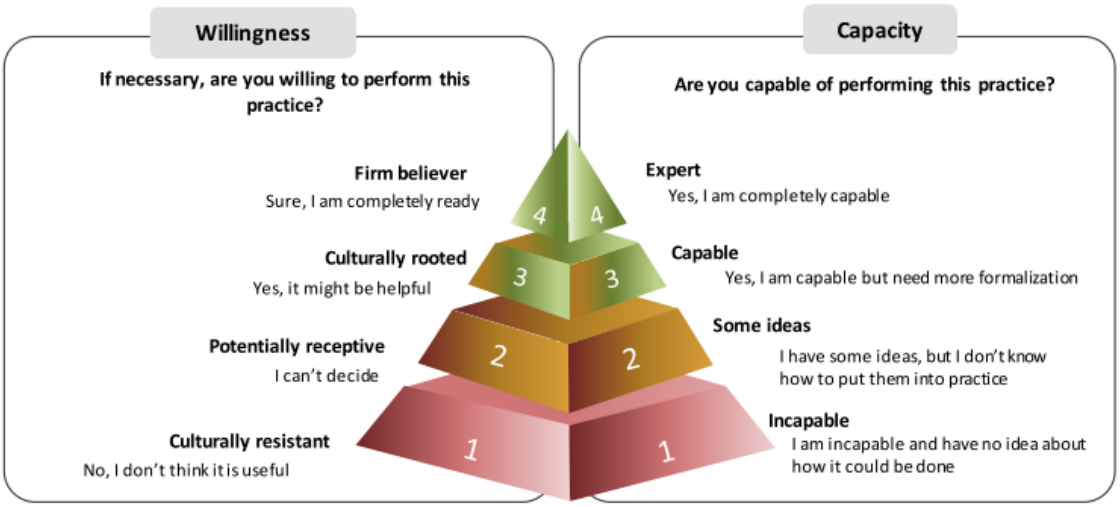


Figure 3-3. Definition of linguistic scale for criteria [5]

The scale was implemented in this way to create a global maturity scale which is later used to represent the evaluations in the form a maturity grid. Maturity grids have been applied to the areas of supplier partnership maturity and innovation maturity in the past and are used to summarize a firm's maturity in terms of predefined phases [47]. To assess the phase of an actor's ACAP maturity, Benhayoun defined a global ACAP maturity scale as shown in Figure 3-4. The capacity evaluation is shown along the horizontal axis while the willingness evaluation is shown along the vertical axis. Based on their location within this grid, practices can then be identified as falling within four predefined phases of maturity: (1) critical, (2) untapped, (3) uncontrolled, or (3) champion [5,8]. This maturity

grid will later be used to structure our representation of the results of the evaluation as it was during Benhayoun's work.

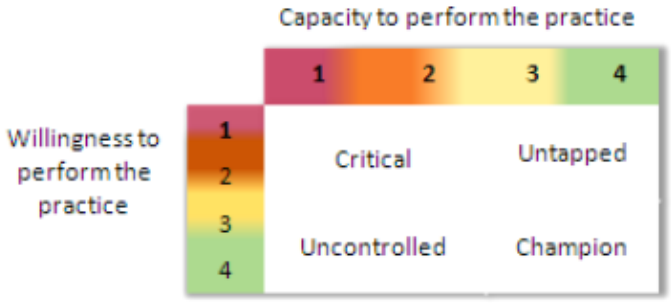


Figure 3-4. Global ACAP maturity scale [5]

Continuing with our previous example involving 8 criteria, example evaluation results are included in Table 3-6. To produce a score from these values, each is divided by the maximum value of the scale: 4. Note that irrelevant criteria which are not shown would receive a score (and weight) of zero.

Table 3-6. Example evaluations of capacity and willingness

i	*Capacity*	*Unweighted Score*	*Willingness*	*Unweighted Score*
1	1	25	1	25
2	3	75	2	50
3	4	100	3	75
4	4	100	3	75
5	4	100	3	75
6	3	75	4	100
7	2	50	4	100
8	3	75	4	100

3.2.4 Aggregation of Weights and Evaluations of ACAP Maturity

Next, WSM is used to aggregate the normalized weights with the unweighted evaluation scores from the previous sections. Note that only relevant criteria have an influence on the aggregated scores. The final scores are rounded to the nearest whole number as further specificity is not needed. This also eliminates any rounding effects of earlier steps. Following equation (2-6), the calculations for weighted scores of each relevant practice as well as the overall aggregate sums for the dimension are shown in Table 3-7.

Table 3-7. Aggregate maturity scores for single actor within a single dimension of ACAP

i	*Weighted Capacity Score*	*Weighted Willingness Score*
1	7.9051383	7.9051383
2	13.043478	8.695652
3	13.833992	10.375494
4	10.27668	7.70751
5	10.27668	7.70751
6	7.70751	10.27668
7	1.5810275	3.162055
8	2.3715413	3.162055
SUM	**67**	**59**

This process of calculating aggregate maturity scores for the actor being evaluated would be repeated for each of the nine dimensions of ACAP producing 9 scores of capacity and 9 scores of willingness per actor. To produce network scores, this process must be repeated for each actor involved in the project in question. The entire process leading up to this point is unique to each actor including the elicitation of project context, importance weights, and maturity evaluations.

It is possible that certain dimensions might not have any relevant practices, may only have one practice, or may only have practices which share the same rank of importance. For cases where there are no relevant practices for a dimension, the scores for that dimension are automatically 0. This is the only way scores can be below 25 using our method of calculation. The meaning of a score in this case is simply that the dimension was not highly relevant and therefore the maturity of the actor for this dimension is entirely unimportant. Alternatively, if a dimension only has one practice that practice would automatically hold 100% of the weight. In cases where practices all share the same rank, these criteria would equally share the importance weight.

3.2.5 Weight Elicitation of Role Criteria

The following steps are used to calculate aggregate scores of the network based on the ACAP maturity scores of its actors. Out of necessity, those who would be evaluating the importance of actors are also members of the actors themselves and thus it is expected that this might introduce bias. We have therefore structured our approach to distance those doing the evaluating from those being evaluated to limit this bias as much as possible.

To do this, role-based criteria were introduced. These roles are specific to the context of innovation promoters within a CIN. Thus, any actor involved in the innovation process would expected to be at least partially implicated in at least one of the following roles as shown in Table 3-8.

Table 3-8. Roles within a CIN

Role	*Description*
Champion and powerful promoters	Those who are directly concerned with the results and are negatively or positively affected based on the success of the project. These promotors are generally responsible for the ***leadership*** of the project,

	determine which actors are included in the network, and have more ownership of the ***intellectual property*** created.
Expert promoter	Those who are responsible for the ***technical coordination*** of the project
Process promoter	Those who facilitate the ***management*** of the project
Relationship promoter	Those who act as liaisons with the market and are responsible for the ***commercialization*** of the project

The more that an actor is involved in one or more of these general roles, the more critical it is to the achievement of network objectives [5,48–51]. The main characteristics of these roles were exacted to produce the 6 role-based criteria as shown in Table 3-9.

Table 3-9. Role criteria for evaluating actor importance

Criteria	*The degree of involvement of an actor…*
1	As the primary leader of the project
2	As the owner of intellectual property of the project
3	As the determiner of which new actors to include in the network
4	As the promoter and leader of commercialization of the project
5	As the manager of the collaboration of the project
6	As the technical coordinator of the project

By using evaluating the importance of roles, a DMs can more honestly apply importance weights without directly considering the actors themselves. This degree of separation is believed to reduce the effects of self-importance bias. This is particularly important if this evaluation is done by a group of DMs rather than a single expert as it will hopefully increase the likelihood that the group is able to reach a consensus on actor weights.

Pairwise comparison was used to determine the importance of these roles. We chose to redefine Saaty's original fundamental scale as was shown in Table 2-1 to make the process more intuitive to users of our tool. It is not expected that those using our tool will be will be familiar with the original scale; thus there were concerns that representing the linguistic

scale using fractional values may be confusing to the DMs. We opted to instead use a positive-negative scale which is then translated within the calculations back into Saaty's original 9-point scale as defined in Table 3-10. Example data using our redefined scale is shown in Table 3-11. The translated matrix with the results of the importance weight calculations is included in Table 3-12.

Table 3-10. Redefined pairwise comparison scale

	A lot more important		More important		Same importance	Less important		A lot less important	
DM Scale	4	3	2	1	0	-1	-2	-3	-4
Saaty's Equivalent	9	7	5	3	1	1/3	1/5	1/7	1/9

Table 3-11. Example role criteria data with redefined scale data

	C1	C2	C3	C4	C5	C6
C1		3	2	0	-2	-2
C2			1	-2	-1	-2
C3				2	-3	2
C4					-1	4
C5						-2
C6						

Table 3-12. Example role criteria weight calculations with data translated into Saaty's scale

	C1	C2	C3	C4	C5	C6	**SUM**	**Weight**
C1	1	7	5	1	1/5	1/5	14.4	0.174
C2	1/7	1	3	1/5	1/3	1/5	4.88	0.058
C3	1/5	1/3	1	5	1/7	5	11.68	0.141
C4	1	5	1/5	1	1/3	9	16.53	0.199
C5	5	4	7	3	1	1/5	19.20	0.231
C6	5	5	1/5	1/9	5	1	16.31	0.197

SUM	83.00

As only 6 criteria are being compared, it is not necessary to allow the DMs to use intermediate values of the original scale; thus, these have been excluded for simplicity. To calculate the normalized weights of importance for each of these 6 criteria, each row of the comparison matrix is summed and then divided by the total sum following the WSM approach from equation (2-6) as is standard practice within AHP as shown in Table 3-12. For simplicity, only the upper half of the matrix was elicited from the DMs due our time restraints. Coherency of the matrix is not required though is preferred. As it is not of direct interest to the DM and so that we do not over constrain our DMs, the calculation of the coherency of the matrix will not be considered further.

3.2.6 Weight Elicitation of Involvement of Actors

Point allocation was then used to elicit the percentage of involvement of actors. Through consensus, DMs consider the percentage of involvement in each of the 6 role criteria from Table 3-9. As true (or estimated) percentages of involvement in certain roles may be objectively defined even before the start of the project, it is believed that this direct style of elicitation will be reasonably simply for DMs even in a group setting. Example percentage values for a network composed of 3 actors working on the same project is shown in Table 3-13. Note that each column must add to 100% for each criterion.

Table 3-13. Example percentages of involvement in role criteria of 3 actors

	C1	C2	C3	C4	C5	C6
Actor 1	25%	50%	20%	33%	30%	0%
Actor 2	50%	10%	20%	33%	30%	20%
Actor 3	25%	40%	60%	34%	40%	80%

3.2.7 Aggregation of Weights and Actor Scores

Finally, the scores of individual actors are aggregated with the aggregated weights of actors following the WSM approach. First, for each of m number of actors a the sum of the weights of each role criteria w is multiplied by the percentage of involvement p for each role r as shown in equation (3-7). This sum is referred to as an actor's aggregate weight W.

$$\sum_{r=1}^{m} w_a p_r = W \tag{3-7}$$

Next, for both measures of maturity for the first 6 dimensions of ACAP framework, the sum of the aggregate weights and the dimension maturity scores s for each of the n actors are found as shown in equation (3-8). This sum is referred to as the network aggregate score S.

$$\sum_{a=1}^{n} W_a s_a = S \tag{3-8}$$

This results in 12 network aggregate scores: 6 for capacity and 6 for willingness. The reason that only the first 6 dimensions of the ACAP framework are considered is that the one-way learning phase is not applicable at the network level. The one-way learning phase is not collaborative and does not involve reciprocal learning, therefore aggregated scores for this phase have no valuable meaning. Example maturity scores of 3 actors belonging to the same network collaboratively working on the same project are shown in Table 3-14. Using these actor scores, the example role criteria weight data from Table 3-12, and the

percentage of involvement of these actors in each of these roles from Table 3-13, the scores of the network were calculated as shown in Table 3-15.

Table 3-14. Example scores for capacity and willingness of 3 actors within the same CIN

	Actor 1		Actor 2		Actor 3	
	C	W	C	W	C	W
D1	39	93	59	43	25	37
D2	48	62	30	96	73	48
D3	85	94	58	56	84	46
D4	83	46	55	68	83	56
D5	78	57	92	81	34	30
D6	39	30	54	54	76	84
D7	-	-	-	-	-	-
D8	-	-	-	-	-	-
D9	-	-	-	-	-	-

Table 3-15. Network aggregated scores

	C	W
D1	41	55
D2	51	69
D3	75	63
D4	73	57
D5	67	56
D6	58	58
D7	-	-
D8	-	-
D9	-	-

Similar to the individual actor scores, the network scores can now be used to compare the maturities between dimensions as well as the capacity and willingness within each dimension. This can be used to identify strengths and weaknesses within the network as to and to gain insight into the ACAP maturity profile of the network as a whole. Consideration of the scores of individual actors can be used to diagnose certain weaknesses as needed, however the scores of individual actors should never be directly compared to other actors.

3.3 Development of Tools

The mathematical approach described in the previous section was applied to create two computational decision-aid tools. Both tools represent the ACAP maturity scores of either the actor or the network as graphic profiles. The abstraction of these profiles is intentionally implicit and relies heavily upon the interpretation of a DM to gain meaning. Note that these tools are simply decision-aids and not decision-making tools; all decision reasoning must be done by the DM. The purpose of these tools is to analyze the strengths and weaknesses of an actor and/or their network regarding their ACAP maturities [52].

Both tools were created in Excel 2016 and rely heavily on the use of VBA macros. The tool was designed for use at two CINs in France, thus the tools were originally developed in French rather than English. The language used within the tool has been thoroughly reviewed by native speakers and should be both correct and natural for French speaking users of the tool. The following sections will describe each tool exclusively in English however the original French tool and a glossary of key terms defined in French is available upon request.

The sheets within both tools are password protected to ensure that the user cannot change the functionality of the tools. If members of the CIN wish to further develop either of these tools this password would be required to do so.

3.3.1 Individual Actor Tool

The individual actor tool exists as an Excel workbook composed of 7 sheets visible to the user organized as the following: (1) introduction to actor tool, (2) DM elicitation of project context, (3) DM elicitation of ACAP practices importance, (4) DM evaluation of

capacity and willingness, (5) results, (6) plan of action template, (7) survey of pertinence of tool. A single expert DM, ideally a member of the actor being evaluated, acts as a representative of the actor to auto-evaluate their own ACAP maturity. This original version of the tool is available upon request.

3.3.1.1 Introduction to Actor Tool

The introduction sheet defines key concepts and includes a diagram illustrating the nine dimensions of ACAP. This sheet also explains why the tool should be used as well as an overview of its organization and how it should be used.

3.3.1.2 DM Elicitation of Project Context

The next visible sheet elicits the context of the project to determine the relevancy of practices. Each practice is given a numerical value of relevancy based on the user inputs to this sheet. Data validation is used to force the user to input only whole numbers within the range of the 6-point scale. A relevancy threshold calculated based on the results of this sheet then determines which practices to hide or show on future sheets.

3.3.1.3 DM Elicitation of ACAP Practices Importance

The importance of practices is then elicited on the following visible sheet. The user is first given general recommendations on how to complete the process based on common mistakes found during usability studies. Next, the user is given detailed instructions on completing SRF organized in 3 steps: (1) rank the practices, (2) determine the difference of importance between ranks, and (3) determine how many more times the most important rank is compared to the least important. Finally, a summary and illustrative example is

given to clarify the user's understanding. The user is then tasked with following these steps for each of the nine dimensions of ACAP.

Irrelevant practices are automatically hidden, and only relevant practices are displayed. Cells needing user inputs are highlighted using Excel's standard user input cell format. The user has the option of doing all of step 1 for all dimensions before proceeding to the next steps or they can choose to do all steps of each dimension before proceeding to the next dimension as they prefer. However, user input locations are only shown after the previous step has been completed. For example, step 2 user input locations would not be displayed until after user inputs to step 1 have been made. Similarly, step 3's user input location only shows after a user input has been made to step 2.

The user is also given the option of clicking on intermediate validation buttons within each dimension of ACAP. These buttons run a series of macros which display messages specific to a series of error types which explain the location of the error and how to fix it. These errors are based on the following logic statements for each dimension:

- If step 1 has not been fully completed
- If step 1 does not have at least one rank at 1
- If step 1 ranks are not consecutive
- If step 2 does not have at least interval defined as 1 unit
- If step 3 is not at least greater than 1

If a step is not necessary, such as for situations where there are no relevant practices, only one relevant practice, or all practices share the same rank, then the error messages for that step are not displayed. If no other error messages have been triggered, the macro displays that the dimension has been properly validated. Only one message is triggered per

click of the button so that users address problems systematically. This process of validation was done to force the user to properly use the method as the theoretical validity of the method is highly reliant upon proper use of the method.

At the end of the sheet the user must click an additional validation button for the sheet. This validation button runs processes necessary for the calculations of the normalized practice weights and formats the evaluation sheet so that only relevant criteria are shown. If the user forgets to click this button, they will have another opportunity to do so on the following sheet.

3.3.1.4 DM Evaluation of Capacity and Willingness

The evaluation sheet then asks the user to rate the actor they are representing on their capacity and willingness to perform relevant ACAP practices. Although many MCDM algorithms including ELECTRE, MAUT, and SMARTS generally have the user evaluate criteria prior to indicating preferences, there is no procedural requirement that the elicitation of importance must come before the evaluation of criteria [15,17,20]. We chose to purposefully order them in this way in hopes that the user is more honest in their evaluations if they understand that less important criteria have less impact on their final scores compared to the impact of more important criteria.

For this sheet, the user is first given instructions to complete the evaluation of capacity and willingness for each relevant practice using the predefined scale for each of the two criteria types. The user also has the opportunity at this point to click the validation button if it had been skipped on the previous sheet. The 4-point scales to be used are included at the top of the sheet and have been frozen to allow for easier reference during evaluation.

Relevant practices are listed adjacent to two columns for each criteria type – capacity and willingness – which the user now completes for their respective actor for each of the nine dimensions of ACAP. Data validation forces the user to input whole numbers between one and four following the scale.

3.3.1.5 Results of Actor

Hidden sheets calculate the ACAP maturity scores based on the previous elicitations. These raw values are then graphically represented as a radar chart and presented to the user. Using the example data shown in Table 3-16 the resultant radar chart is shown in Figure 3-5.

Table 3-16.Example resultant scores of an actor

	Capacity	Willingness
Preparation Acquisition	82	83
Preparation Assimilation	75	75
Preparation Application	88	63
Achievement Acquisition	77	100
Achievement Assimilation	71	83
Achievement Application	89	72
One-way Learning Acquisition	85	57
One-way Learning Assimilation	54	39
One-way Learning Application	96	90

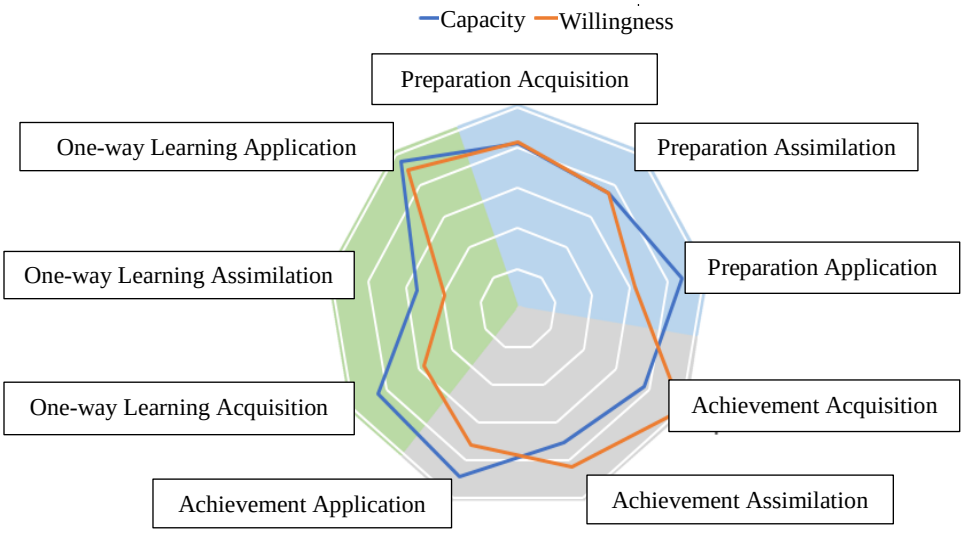


Figure 3-5.Example radar chart based on actor scores

A button adjacent to the raw calculated scores runs a macro which copies these scores to the clipboard for later exportation into the network tool when needed. Also included on this sheet are the measures of relevancy for each dimension as calculated based on the project context responses. Instructions for interpreting these results are also included on this sheet.

From the work of Benhayoun, the reference numbers of each relevant practice are also organized within maturity grids belonging to each dimension of ACAP as explained in §3.3. For easy reference, the descriptions of the corresponding practices for these reference numbers as well as the calculated normalized importance weights are included adjacent to the grid. These items together help the user diagnose specific weaknesses of high importance within a particular dimension to best create their plan of action.

3.3.1.6 Plan of Action and Survey of Pertinence of Actor Tool

These two sheets remain largely the same as they were in Benhayoun's tool. The first of these provides a simple template for creating a plan of action based on the results

obtained from the tool. The later pertinence sheet requests for feedback on the tool to determine its ease of use, accuracy, and usefulness which must then be submitted back to tool developers – either within the CIN or back in academia – to improve the tool further.

3.3.2 Network Tool

After actor scores have been found for all actors within a CIN for a particular project, the network tool can be used to aggregate these scores to determine the dimensions of ACAP which are the most critical to CIN objectives as well as which actors are the most well equipped in potentially handling identified weaknesses. To do this, ideally a representative from each actor of the CIN would convene to jointly use the network tool, however it is expected that this will sometimes be nearly impossible particularly for CINs whose actors are not collocated. In these scenarios, a single expert representative of the CIN who is knowledgeable on the roles of actors within their network can be used. The tool has been designed to encourage group consensus without implementing any further decision aids to this process.

This tool is structured similar to the tool used to evaluate individual actors. It is a separate Excel workbook composed of 7 visible sheets: (1) an introduction to the tool, (2) comparison of role criteria, (3) comparison of actor involvements in roles, (4) score importation, (5) results, (6) plan of action, and (7) survey of pertinence of tool.

3.3.2.1 Introduction to the Network Tool

This sheet introduces the objective of the tool as well as the role-based criteria that will be used to weight the importance of actors. How the tool is structured and will be generally used is then explained. A detailed explanation of how to import actor data into this

workbook is also explained. Finally, how to properly interpret the results of the evaluation is then given as well as brief instructions for use of the plan of action and survey sheets.

3.3.2.2 Comparison of Role Criteria

The scale used for comparing the importance of each of these roles to CIN objectives is defined and an explanation of how to author a pairwise comparison matrix is clearly explained through an example. Drop down lists and data validation force the user to only input whole number values within the range of the predefined scale.

The user is allowed to initialize the matrix using a button at the top of the sheet which sets all matrix values equal to zero meaning that all criteria have the same weight. After systematically discussing each comparison, the group of DMs would then adjust each value based on their preferences.

3.3.2.3 Comparison of Actor Involvements in Roles

The user is instructed to list the names of actors in their CIN in the first column of the matrix. Although only four or five actors are generally expected, the maximum number of actors able to be defined here is ten. Point allocation becomes increasingly less accurate for scenarios with many criteria, therefore it is not reasonable to use our proposed method for networks with many, many actors. For this reason, a maximum of ten actors was believed to be appropriate.

This user defined list of actors is used to populate the dropdown list which will later be used within the score importation sheet. Next, the user is instructed that each column corresponding to each of the six role-based criteria has 100 percentage points. The DMs would now discuss how these points should distributed and then input the corresponding

values at the intersection of each actor and role within the matrix respectively. At the top of each column is a sum of total points distributed for that column which the user is reminded should be 100 when complete. To avoid having too many interruptions to group conversation, no validation messages were implemented here.

3.3.2.4 Score Importation

Based on personal past experience in industry designing Excel forms which require the importation of data, it has been found that users often struggle with this step. For this reason, the process has been automated as much as is possible within Excel using button triggered macros. First, the user must locate the results matrix of an actor within their CIN they wish to import. Next to each of this results matrix is a button which triggers a macro which copies the data from the matrix. Now, the user is must to navigate to the network workbook's score importation sheet and click an import button adjacent to an empty matrix. This button triggers a macro which then pastes the data into the adjacent import matrix. Finally, the DM must find the name of the actor in the dropdown list also adjacent to this matrix. These lists are automatically populated after adding actors to the comparison of actors sheet.

3.3.2.5 Results of Network

Similar to the calculations for done to calculate the scores of individual actors, the calculations of network scores based on the DMs inputs to the previous sheets are hidden from the user. The results are then shown to the DM in the form of a radar chart whose interpretation remains the same. However, the three dimensions within the one-way learning phase are not shown. The reason to exclude these from the results is because at

the network level they have no meaning. The ACAP practices which occur during the one-way learning phase are only intended to bring direct benefit to individual actors. There are therefore no improvements to the network level innovation strategy which can be reasonably made for this phase.

Next to the radar chart is stacked bar graph illustrating the relative weights of importance of actors within the network. This does not mean that important actors are necessarily the strongest, however it does mean their ACAP maturities are more critical to network objectives.

Below these are two additional radar charts which can be used to compare the influences of specific actors on the network score. The actors are listed in the middle of the two charts. Toggle buttons adjacent to each actor name can be used to toggle whether each actor is shown on the radar charts or not. This allows for the user to isolate and compare specific actors. These comparisons can be used to compare the strengths and weakness of actors and their influences on the network but is not intended to be used to say that one actor is better or worse than another actor.

3.3.2.6 Plan of Action and Survey of Pertinence of Network Tool

These two sheets again remain very similar to their equivalents within Benhayoun's original tool, however the questions for the survey have been updated slightly to be applicable to the network as a whole.

3.4 Usability Study Protocol

In order to iteratively improve the functionality, validate its usability, and receive initial feedback on the perceived usefulness of the individual actor tool a protocol for usability

studies was used. Protocol studies such as these are used to explore complicated behaviors in a controlled environment with a predefined analysis protocol. These studies are generally limited to a few hours and focus on the detailed understanding of the behaviors of just a few individuals. They are used to test tasks or tools to understand how or why a behavior occurs [53–55]. We chose this type of study because we were interested in exploring the usability and perceived usefulness of the tool which are both characteristic of the user. The true usefulness of the tools was not able to be measured due to time limitations and lack of access to true end users, however this will be further explored in Part 2.

The usability study protocols were adapted from Krug's common sense approach from his book *Don't Make Me Think* [56]. An English version of Krug's original protocol can be found on his website[1]. Our testing was done in two phases: (1) pilot usability studies with experts (2) and iterative usability studies with non-experts.

The focus of the first phase of pilot studies was to test our protocol and to understand the perceived usefulness and understandability of the tools rather than focusing heavily on their functionality. The experts which were used in these studies were all faculty of G-SCOP with experience working on projects with or within SMEs. We therefore assume that the results of the studies using these experts are able to be used as estimates of true end users as true members of SMEs were not available.

The second phase was done through multiple iterations of usability studies with non-experts. All non-experts were Masters students working on research projects within or

[1] https://www.sensible.com/downloads-rsme.html

partnered with GSCOP. These non-experts are not considered as good estimates of members of an SMEs representing an actor within a CIN as their levels of experience working with or within SMEs was limited. Thus, these studies focused on the understandability of the tool despite lack of expertise as well as the functionality of the tool.

Although some users – expert and/or non-expert – were slightly familiar with the concept of ACAP as a result of contact with those directly involved in the ACIC research project, none could be considered experts on the topic. Similarly, we expect that our true SME end users will not have a strong if any background in topics directly related to ACAP maturity. All studies were conducted in French and administered by myself following the aforementioned scripts. The scripts used for the expert and non-expert studies are available upon request, however their structure is almost identical to those used during Part 2 which are included in Appendix B.

The scripts were intentionally written using natural language to encourage users to speak freely during the study. As I do not yet speak naturally in French myself, I was forced to heavily rely upon this script in how I administered the study. This is believed to have actually had a positive impact on the reliability of the results as it required that studies stay true to the protocol. Despite my own language deficiencies, I was still cable of keeping users engaged in speaking aloud during tests and to make necessary changes to the protocol as needed to accommodate to the needs of the user or to probe the user for more specific information. Furthermore, this slight language barrier also helped to ensure that I, as the administrator, did not over-intervene in the study which is critical to the purpose of a

usability study. During expert tests, an additional observer who was fluent in French helped facilitate the study to elicit additional detailed feedback from users to fully gauge their understanding (or lack thereof). For non-expert tests, I was the only administrator present, however audio recordings of the tests were used to ensure that user feedback was accurately captured. Although all expert users were native French speakers, some of the non-experts used for our studies were not.

Following the script, the user is first introduced to the purpose of the study and how it will operate. Throughout the script the users will be reminded that the purpose of the study is to evaluate the tool and not them therefore they should feel free to make errors. At the end of this introduction, the user is asked to sign an authorization document analogous to an IRB statement which gives us permission to record and report upon the results of the study. This document stipulates that the identities of participants be kept anonymous and that only members of the ACIC research team are privy to listening to the original recordings. After the user signs this document, the audio recording of the session is begun, and the study begins.

First, basic questions into the background of the users are asked to determine the user's familiarity with the topics relating to ACAP and to get users to describe a collaborative project that they have worked on with GSCOP or as a member of GSCOP. Whichever project they choose will be used as their reference project during the study. The user is then asked to navigate through each sheet of the workbook tool without interacting it to become familiar with its general structure.

For the non-expert studies, a scenario is then formally introduced nearly identical to the one used in Part 2 of this work. The scenario as it appeared in the French studies is translated below:

> ***SCENARIO:***
>
> *For the rest of the study, imagine that you represent an SME within a Collaborative Innovation Network (or CIN) and that your network is working together on an innovation project. In this scenario, your research project will be your innovation project, GSCOP will be the SME that you are representing, and all other industrial partners involved in the project are other actors within your network.*
>
> *You may not know exactly what Absorptive Capacity (ACAP) is, however you would like to learn how to use the concept to your advantage. You have received the auto-evaluation tool in front of you in order to do this.*
>
> *It is understood that GSCOP is not truly an SME. You may need to use your imagination during the test. Remember that the objective of this study is for us to evaluate the functionality of the tool and not on its accuracy.*

For the expert tests, the focus of the studies was on understandability of the tool rather than functionality, therefore a scenario was not formally introduced for these studies. This was also done to determine if the user was able to define themselves as a representative of an actor solely based on the instructions within the tool rather than through the use of a scenario. Organic intervention was generally used to prompt the expert users to make this definition as needed.

Next, the way the study will work is fully explained. The user is told that they will be given a series of tasks that they will complete while speaking aloud. They are told that they are welcome to ask questions but that not all questions may be immediately answered. If a task is too complicated or seems impossible the users are allowed to ask to skip the task.

Additionally, if the user would like to take a pause at any point during the test they merely need to notify they would like to do so.

If the user has no questions at this point the first task is introduced. The user has a copy of the script and is allowed to refer back to the scenario or task descriptions as needed. Each task prompts the user to read and complete each sheet of the workbook beginning with the introduction and ending with the results. At the completion of each task the user should notify the administrator before moving onto the next task. The final two sheets – the plan of action and the tool survey – are not included in the study. After being given these initial prompts, the user is allowed to freely complete the sheet as they see fit. A significant amount of intervention was done during the expert studies in order to better evaluate understandability, however an effort was made to remain uninvolved during the non-expert studies to fully evaluate functionality.

After completion of the tasks, the users are debriefed in order to get additional feedback on the tool. Complications which occurred during the study are also investigated at this time. Users are also asked whether they believe that the tool highlighted elements which the user may have underestimated as well as whether or not the tool could be used to help generate conversation within their team or network to make improvements to their innovation strategies.

The study is then concluded and the user is thanked for their participation. The audio recording is then stopped and the study is complete. The user is allowed to leave and the administrator then writes any additional notes or observations made during the study.

Chapter 4. Usability Study Results

Studies were completed with each of 3 expert users and 5 non-expert users. The basic profiles of these users are included in Table 4-1. Expert users were all native French speakers with good familiarity with working on innovation projects within or in partnership with industry in France. These users were able to give detailed feedback on the language and verify its understandability, particularly pertaining to the topics of ACAP which two of the three experts had at least some knowledge of before the study. Three of the non-expert users were also native French speakers and were able to further verify the language used. Benhayoun also provided additional language support during the tool's development and ensured that the more detailed feedback on the language by expert users was fully implemented within the tool. All users had some level of involvement with the GSCOP lab. The expert users were also all involved in the ACIC project though in different faculties.

Table 4-1. Profile of users

	Date	*French Native Speaker*	*GSCOP Involvement*	*Involved in ACIC*
Expert User A	16 April 2018	Yes	Industry consultant and associate professor within GSCOP	Yes
Non-expert User B	18 April 2018	Yes	Masters Intern within GSCOP	No
Expert User C	23 April 2018	Yes	Researcher and Lecturer at GSCOP	Yes
Expert User D	23 April 2018	Yes	Researcher and Lecturer at GSCOP	Yes
Non-expert User E	25 April 2018	No	Masters Intern within GSCOP	No
Non-expert User F	24 April 2018	Yes	Masters Intern partnered with GSCOP	No
Non-expert User G	27 April 2018	No	Masters Intern within GSCOP	No
Non-expert User H	4 May 2018	Yes	Masters Intern within GSCOP	No

During and directly after each study, the administrator of the study took notes based on their observations. The audio recordings of these sessions were then used to verify the written observations as needed and to pull quotes supporting generalizations that were made. Note that all quotes from users have been translated into English based on the original French audio. Based on these observations, changes were made to the tool in hope of improving either its perceived usefulness or its usability. A summary of the significant observations made during each of the 8 studies as well as the resultant changes which were made to the individual tool are included in Table 4-2.

Table 4-2. Summary of major observations and functionality changes

	Major observations	**Major functionality changes to tool**
Expert A	*Elicitation of Practice Importance:* • Did steps out of order: 1, 3, then 2 • Needed explanation of some of the practices, noted that the tool would be difficult to use without a facilitator • Was confused what do when there was only one interval, however the user's confusion helped them figure out the difference in meaning between steps 2 and 3 *Results:* • Confused as to why he had a score of 0 for an irrelevant dimension • Had not well read how to interpret results and did not intuitively understand how without explanation	*Elicitation of Practice Importance:* • Validation button for each dimension added • Validation that step 2 has at least one value equal to 1 unit • Validation that step 3 input is logical
Non-Expert B	*Elicitation of Practice Importance:* • Did not understand step 3 • Validation messages not properly triggered *Results:* • Did not intuitively understand how scores were calculated and seemed not to trust these values as a result • Noted that the phases on the radar chart could be highlighted more for clarity • Referred back to previous sheets to understand which practice was being referenced within maturity grid • Did not initially understand that the grids were organized by phase of ACAP • When discussing how results would be applied reverted back to acting as the individual, not as the actor	*Elicitation of Practice Importance:* • Some fixes to validation and calculations *Results:* • Restructured results so that practice descriptions were included next to importance • Maturity grids are laid out linearly more similarly to how they were during evaluations for clarity • Relative importance represented as a percentage

Table continued…

	Major observations	**Major functionality changes to tool**
Expert C	*Introduction:* • Suggested that explanation of results be included on the results sheet rather than in the introduction *Elicitation of Project Context:* • Sheets did not well fit user's screen, zoom was necessary at times *Elicitation of Practice Importance:* • User preferred to do all of each step across all dimensions before proceeding to next step, did not intuitively grasp dimension structure • Skipped validation button at the end of sheet, intervention had to be made to correct it *Evaluation of Capacity and Willingness:* • Complained about needed to refer to top of sheet for scale *Results:* • Noted that color coding phases of ACAP on radar chart would add clarity	*Elicitation of Practice Importance:* • Some fixes to validation and calculations *Evaluation of Capacity and Willingness:* • Repeated final validation button from previous sheet at the top of this sheet to ensure it does not get skipped *Results:* • Radar chart color coded based on ACAP phases
Expert D	*Introduction:* • Was able to give a brief summary as to what they needed to do however noted that they did not fully understand the explanation of the results this early on *Elicitation of Practice Importance:* • Wanted to all of step 1 across dimensions before proceeding to next step • Confused about the difference between steps 2 and 3 to the point where intervention was required • Found it cognitively difficult to do step 3 once understood • Had missed existing diagram explaining step instructions and complained that there was not such a diagram	*Elicitation of Practice Importance:* • Some fixes to validation and calculations

Table continued…

	Major observations	**Major functionality changes to tool**
Non-Expert E	*Elicitation of Project Context:* • Despite understanding scale, attempted to put value outside of this scale because it was possible *Elicitation of Practice Importance:* • Triggered validation messages but clicked out of them without reading them, repeated this multiple times • Validated final button and understood that the button at the top of the next sheet had the same function just in case, repeated button did not cause confusion	*Elicitation of Project Context:* • Added data validation to ensure scale is correctly used *Elicitation of Practice Importance:* • Validation added to check that all criteria are ranked • Validation added to check that at least one practice in each dimension is give a rank of 1 (to check that ranking process was started correctly) *Evaluation of Capacity and Willingness:* • Added data validation to ensure scale is correctly used
Non-Expert F	*Introduction:* • Noted that there seemed like too much text to process at the beginning *Elicitation of Project Context:* • Struggled to understand who the other actors were on her project *Elicitation of Practice Importance:* • Seemed to correctly understood process however did trigger validation on step 3 after 4 dimensions but was able to troubleshoot • Also triggered validation on step 2 as the smallest interval was not 1, but was not able to troubleshoot problem; intervention had to be made *Evaluation of Capacity and Willingness:* • Noted that having to refer back up to the scale during the evaluation was cumbersome	*Evaluation of Capacity and Willingness:* • Scale frozen for easier viewing during evaluation

Table continued…

	Major observations	**Major functionality changes to tool**
Non-Expert G	*Elicitation of Practice Importance:* • Language posed some problems with understanding, some minor interventions in English were done for clarity • High level of understanding, was able to explain back the process • Occasionally found it easier to identify the least important practice for step one and work their way up rather than the other direction, this resulted in some ranks accidently being skipped despite understanding of the method *Results:* • Was not surprised by results • Was able to properly interpret scores, relative importance values, and maturity grid • Noted color coding of radar chart encouraged comparison between phases	*Elicitation of Practice Importance:* • Added validation for consecutive ranks • Added some initial instructions to clarify common mistakes • Updated instructions and validation to allow users to complete steps by order of step then dimension or by dimension and then step
Non-Expert H	*Elicitation of Practice Importance:* • Heavily rationalized response for step 3 in terms of response for step 2, when asked to elaborate upon their meaning it was found that they perfectly understood the meaning of step 3 and how it differed from step 2 *Results:* • Was able to understand and interpret scores but could not be easily prompted to consider importance directly	*Elicitation of Practice Importance:* • Replaced existing example and diagrams with a new written summary with clearer example and diagram based on how process was explained to both participants G and H which resulted is strong understanding of the process *Results:* • Moved instructions for interpreting results from introduction to this sheet for clarity

The objective of these studies was to determine whether the tool and the process of using it was perceived as both useful and usable. *Usefulness* refers to the level of perceived utility and applicability of the tool. *Usability* refers specifically to the ease of which the tool can be used. This is strongly connected to the functionality of the tool rather than its usefulness. Ideally neither the usefulness or usability of the tool should rely too heavily on

the expertise of the user or the involvement of an outside facilitator which is why *understandability* of the language and explanations within the tool is also of critical importance to consider. A summary of the initial and intermediate understanding, perceived usefulness, and ultimate satisfaction with the usability of the individual tool exhibited during each study is included in Table 4-3.

Table 4-3. Summary of user understanding and feedback on usefulness and usability

	Before		During			After	
User	*Familiar with ACAP or CINs?*	*Familiar with methods?*	*Represents actor understood?*	*Unit of difference understood?*	*Z-factor understood?*	*Perceived usefulness?*	*Satisfaction with usability?*
Expert A	Some familiarity with CINs	No	No: Struggled to understand that he represented all of GSCOP in his project	Not initially: did step 3 then step 2 relative to step 3, then naturally realized one interval had to be equal to one unit and redefined his responses to step 2 accordingly; correctly used unit from then on	Yes	Yes: Was able to determine specific ways they might apply the results	No: Believed that the tool was nearly impossible without a facilitator present
Non-Expert B	Some familiarity with CINs	No	Yes	Somewhat: Tended to use the same unit across dimensions rather than redefining the unit each time but usually caught the error and corrected themselves	No: Heavily based step 3 response on step 2, some invalid responses given which were not caught by validation	Somewhat: Preferred to analyze project in terms of their new understanding of ACAP rather than actually using the scores themselves	No: Noted that the they believed elicitation of practice importance would be too complicated for industry, however did also noted that the validation helped them troubleshoot this complexity
Expert C	Involved in ACIC project, familiar with both	Some familiarity with pairwise comparison	Yes	Seemingly, test not complete	Seemingly, test not complete	Seemingly, test not complete, usefulness limited	No: Noted that they believed that the tool seemed too time consuming and complicated for industry

Table continued…

User	Before		During			After	
	Familiar with ACAP or CINs?	*Familiar with methods?*	*Represents actor understood?*	*Unit of difference understood?*	*Z-factor understood?*	*Perceived usefulness?*	*Satisfaction with usability?*
Expert D	Involved in ACIC project, familiar with both	No	Yes	Not initially: Intervention had to be made	Not initially: Intervention had to be made, once understood found this process particularly difficult	Somewhat,	No, step 3 of the elicitation of practice importance seemed to cause them to loose confidence in their results
Non-Expert E	No	Some familiarity with pairwise comparison	Yes	No: Was not able to troubleshoot errors	No: Was not able to troubleshoot errors	No: Rushing and understanding of the language had prevented any useful understanding	No: Thought that reliance on text made the tool too complicated
Non-Expert F	No	No	Yes: However, had some difficulty with processing who were considered other actors in their network	Somewhat: Seemed to intuitively define at least one interval at a unit of 1 for each dimension without realizing that this was obligatory	No: However was still able to give logical answers with one exception which they were able to quickly troubleshoot using validation messages, at end however it was still not understood why this was not automatic based on the responses for step 2	Unclear, content will the results and found them logical but difficult to prompt to find a true application of the results	Unclear
Non-Expert G	No	Some familiarity with pairwise comparison	Yes	Yes: Gave evidence of strong understanding	Yes: Gave evidence of strong understanding	Yes, indicated the results would help in a collaborative environment in his office or communicating with other actors	Yes, Strong understanding of results though still found elicitation of practice importance particularly complicated

Table continued…

	Before		During			After	
User	*Familiar with ACAP or CINs?*	*Familiar with methods?*	*Represents actor understood?*	*Unit of difference understood?*	*Z-factor understood?*	*Perceived usefulness?*	*Satisfaction with usability?*
Non-Expert H	No	No	Yes	Yes	Yes: Always gave logical answers however strongly related response back to step 2, when asked to explain the meaning of step 3 was able to properly interpret meaning	Yes, Useful though felt like more time for needed to properly get use out of it	No, Strong understanding of how to interpret results but found using the tool exhausting particularly by nature of their innovation project

Between iterations, significant changes were made to the language used within the instructions for using SRF to elicit practice importance in order to improve its understandability. Throughout testing, the process of using SRF was continuously identified by users as the most complicated aspect of using the tool. Users did not appear to have any notable difficulties with the first step of the process which simply had users rank the practices for each dimension by their order of importance, however the two steps following did pose significant difficulty. The primary difficulty was in understanding the difference between what was being asked in step 2 compared to what was being asked in step 3. Non-expert F stated, "It wasn't evident to me [..] After I've defined the unit of difference between ranks 1 and 2 and then ranks 2 and 3, why can't step 3 then be done in an automatic way?" This confusion appeared to be caused partly by the large amount of text needed to fully explain the process – which users often had a habit of skimming through without fully understanding – but also by the lack of intuitiveness of the method contrary to what literature had suggested [16]. One reason for this lack of intuitiveness is

the difference in how the method was originally applied versus our approach. Originally, Simos' method was designed to be applied with the help of an expert facilitator using physical cards which the DM would manipulate to indicate their preferences. The process, once well understood with the help of the facilitator, was believed to be well adapted to how DMs naturally perceive their preferences which holds true even within our studies. However, without a facilitator being directly involved as is expected to be the case when our tool is deployed at industry, the understanding of this process was found to be not highly intuitive at all. It is most likely for this reason that Simos' style of weight elicitation is one of the least popular subjective weight elicitation method to apply as a software application – only the software developed by the original authors of the method has even been found [18].

Over the course of the studies, intervention had to be made by the administrator to further explain the SRF process. For the final two studies, the administrator explained the process by illustrating a simple example which resulted in both participants exhibiting strong understanding of the meaning of these steps. In the final version of the tool, this illustration and example was also added. The illustration translated into English is shown in Figure 4-1 below.

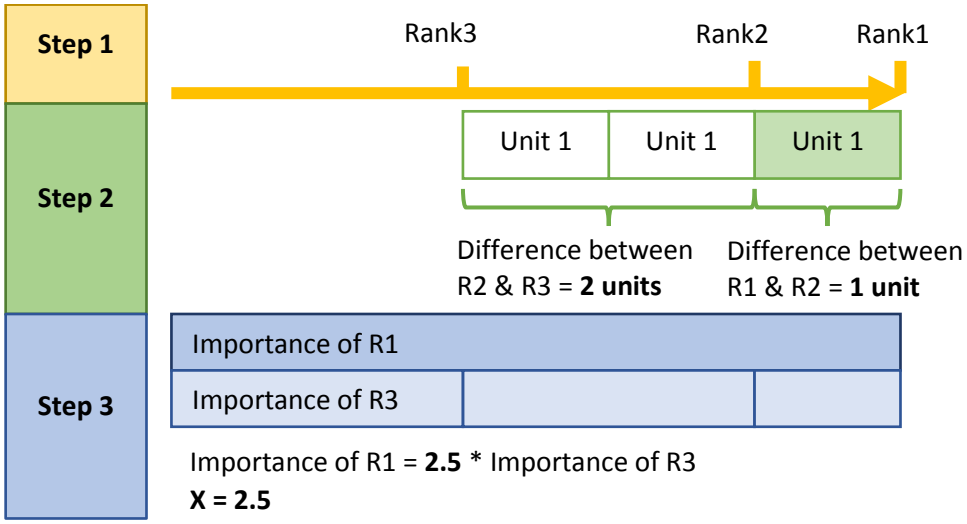


Figure 4-1. English translation of illustration of SRF steps

Although it was originally expected that all users would complete each step of SRF for each dimension before moving on to the next dimensions, some users found it easier to process the instructions if they completed all dimensions for each step before proceeding to the next step. This unforeseen strategy for using the tool posed some problems to the tool's functionality as it resulted in users being more likely to not use validation buttons at all or to only use validation buttons late in the process after having already completed a large quantity of the elicitation. In this later case, this meant that users risked having to redo large portions of the elicitation which was already found to be at least a somewhat exhausting process by most users. To remedy this, a short explanation of strategies to avoid common mistakes was written before the detailed SRF instructions.

The process of using SRF to elicit the importance of ACAP practices took on average 30 minutes for each participant to complete. This is over twice as long as either the elicitation of project context which took an average of 12 minutes or the evaluation of capacity and willingness which took on average 13 minutes. It was originally believed that

the context and evaluation alone would take approximately an hour however during testing it was shown to be only about half of this. Similarly, the process of using SRF was expected to take roughly an hour however it was also much less than this. However, our target values may have been set too high as many users still voiced that they found the process rather exhausting. Non-expert H, despite well understanding the process, even had to request a brief intermission in the middle of using SRF due to mental fatigue. A summary of comparable times is included in Table 4-4. Times were excluded from this table if significant interventions or other necessary deviations from the protocol were made. See Table 4-2 for more explanation regarding protocol exceptions.

Table 4-4. Time needed for users to complete tasks

	Time Needed for Context	*Time Needed for SRF*	*Time Needed for Evaluation*
Expert User A	10 min	18 min	12 min
Non-expert User B	7 min	30 min	15 min
Expert User C	8 min	35 min	-
Expert User D	-	-	-
Non-expert User E	-	-	-
Non-expert User F	11 min	41 min	18 min
Non-expert User G	7 min	25 min	8 min
Non-expert User G	13 min	-	-

Another user – non-expert E – out of frustration with the complexity of the tool and difficulties with understanding the language, opted to complete the tool as quickly as possible without close understanding of the process or topics relating to ACAP. Because of this the user exhibited a lack of confidence in their results and struggled to associate a meaning to the scores or how to apply them which was not surprising. It has similarly been found in literature that by reducing judgmental labor, there is also a reduction in the opportunity to have insights as was evident from this user; however, it has been shown that

the learning gained during the process of eliciting importance weights may be nearly as valuable as the insights gained from the results [20]. The fact that our tool is somewhat complicated may have a certain advantage as it requires the user to make a concentrated effort to understand the concepts of ACAP in order to complete the elicitations and evaluations. For example, non-expert B, chose to rely entirely on their new understanding of ACAP rather than on the scores. When justifying their reasons for choosing to pursue improvements within the preparation acquisition dimension, non-expert B responded that "For the preparation acquisition, its values are relatively in the middle, […] but it's important to start with the preparation acquisition because it comes at the beginning."

Of the users who completed the full process of using the tool, most did find it useful and were able to identify specific improvements they could make based on the result of using the tool. However, most users indicated that they were not surprised by the results or scores. Non-expert G stated "The results to me seemed very coherent relative to what I imagined. […] The results page could be used to show certain points, such as if it were posted on an office collaboration-wall. We could put it there to communicate the results with those working on other parts of the project or with others within our own SME to improve on certain points [on future projects]."

Chapter 5. Summary of Findings

The model which was developed and explored during Part 1 of this work provides an answer with limitations to our initial research question:

RQ: How can methods from MCDM be applied to score the ACAP maturity of actors and their collaborative innovation networks?

During Part 1 of this work, literature from MCDM was used to identify weight elicitation and aggregation methods which could be applied to model the ACAP maturity of actors and their networks. These methods were compared based on method criteria to determine the most appropriate given our application. Based on our findings, it was decided that SRF would be used to elicit the subjective importance weights of ACAP practices. The WSM would then be used to aggregate these relative weights with the maturity evaluations of actors to produce an aggregate score for each of the nine dimensions of ACAP. These scores allow actors to be most heavily evaluated based on those practices which are the most important. These actor scores were then represented as a radar chart to produce an interpretable profile of that actor's maturity in terms of the capacity and willingness to do relevant maturity practices. This model was applied to further develop the ACAP assessment tool which was created during an earlier work package of the ACIC project. This tool was tested through a series of usability studies with expert and non-expert users to analyze the usability, usefulness, and level of understanding of potential users. Due to SRF's necessary complexity, there was a limit to the tools usability, however the tool was still identified as being useful regardless of full understanding of the process.

A network evaluation tool was similarly developed which first introduces role-based criteria which are weighted by a group of actors using pairwise comparison using a

customized scale. Representatives of the network then directly indicate each actor's level of involvement in these roles using point allocation. This two-level hierarchy is believed to reduce bias by not having actors directly rate their own importance. After importing the actor scores of the network, these are then aggregated with the aggregate importance weights of each actor. Both aggregation steps are again done using WSM. These scores are then also represented as a radar chart profile so that they can be interpreted for network level decision making.

Although both the actor and network level tools are believed to be reasonable – though with some concerns to robustness – only the functionality of the actor assessment tool could be validated at this time. This was due to a lack of availability of true end-users within real CINs in France. In absence of real networks of SMEs, the expert and non-expert members of GSCOP were believed to be the next best form of validation. In future work, it is recommended that this tool continue to be tested following the usability study protocol which was developed with true members of a CIN if it desired for use in France.

The largest obstacle to usability which was identified during our research was as a result of the complexity of SRF. We found that SRF was unfamiliar to all participants and was generally non-intuitive. Though somewhat well adapted to the way users cognitively perceive importance, the process was not well adapted to being applied within Excel, particularly without a facilitator present. This most likely explains why there is only one other known software tool developed using SRF which has been published outside of this project. However, we hope that the changes we made to the process of using SRF improves

upon the overall ease of which it can be applied within software by future researchers interested in the method.

PART 2:

FURTHER INVESTIGATION INTO USABILITY

This work occurred while attending Clemson University.

Chapter 6. Return to Clemson University

Part 1 of this research was motivated by academic and industry demand for an ACAP assessment tool able to provide meaningful profiles of actors and their collaborative innovation networks within a project. The ACIC project, which the work from Part 1 had been a part of, was a project funded by research grants with multiple academic partners which had all been involved in different phases of the project's development. However, when it came time to test the tool using partner organizations and real CINs it became nearly impossible to do so. Industry contacts were difficult to contact, and time was running out for development. The ACIC project's contract ultimately ended in September of 2018 which ended any official relationships between academic institutions. Though the project is officially over, development of the tool will still be continued by other developers though the work is no longer funded by research grants and does not currently have identified demand from industry.

Though the developments which were made during Part 1 meet the original objective of that research, ultimately the usability concerns identified within Part 1 prohibited the tool from moving forward on its current development path. After completion of the work from Part 1, it was decided by the development team continuing with the project that the usage of SRF should be eliminated from the individual actor assessment tool. The future of the network ACAP assessment tool remains uncertain and currently untested.

To investigate the degree of which usability had been a consideration of previous researchers within the engineering design enabler community, a literature review was conducted by Gendreau on enablers recently developed by the CEDAR lab [52]. Part of

this review included identifying the method of validation [52]. These tools and their validation methods are summarized in Table 6-1 below. Validation methods are not mutually exclusive of each other, therefore there is some overlap in how they are defined and why they might be used [53]. A *case study* refers to in-depth, objective examinations of uncontrolled, contemporary, and complex phenomenon [52,53,57,58]. Cases have the advantage of being objective as they can be studied without directly influencing the process and generally occur over a long period of time [52,53,57,58]. A *protocol study* uses a controlled environment to explore complicated design behaviors and activities using a predefined analysis protocol [52,53,55,59]. These studies are generally limited to a couple hours at a time and focus on just a few participants [52,53,55,59]. *Experimental studies* compare methods with the goal of fine tuning the tool and method parameters [52,53,60,61]. *Simulation studies* replace human actors with mathematical modeling of the design processes [52,62,63].

Table 6-1. Validation methods used in the development of engineering design enablers by the CEDAR lab, updated based on [52]

Design Enabler	Reference	Validation Method
MODA Packaging Optimization Tool	[64–68]	Case Study
Lazy Parts Identifier Method	[69–71]	Case Study
Feature Recognition Design Enabler	[72]	Case Study
FMEA for Reverse Engineering Tool	[73]	Case Study
FMEA for Flexible Parts Tool	[74]	Case Study
Assembly Time Estimation Tool	[75–80]	Experimental Study, Simulation Study
Heterogeneous Object Material Designer Tool	[81–83]	Case Study
Lamelle Retrieval System	[84–86]	Case Study, Simulation Study
Options Exploration Method	[87]	Case Study, Experimental Study
Frame Configuration Tool	[88]	Case Study, Simulation Study

Interesting, only the assembly time estimation tool was ever tested with representative users as part of its validation. This does not necessarily indicate a failing on the part of the researchers involved in the other nine tools, however it is evidence of common underlying research focus. The validation methods chosen all seek to validate the science which they have developed and not on the application of that science. Even the experimental studies conducted with users for the assembly time estimation tool was done to experimentally test and improve the theory behind the tool, not to improve the user experience; the usability of that tool is never discussed in any of its related publications. It is unclear how many of these tools were ever ultimately implemented in any way as the literature on this is nearly non-existent.

This lack of interest in how well the science is applied has created a lack of motivation to regularly consider usability during the development of engineering design enablers by academics. Usability can be explored and considered very early within the design process,

however it appears to be often ignored. The goal of this research is not to change the purpose of academic researchers within engineering design; instead it is desired to create a list of recommendations to help developers consider usability without necessarily having to complete a single usability study themselves. These recommendations can then be used to improve the likelihood of acceptance of this genre of design research which will in turn increase research dissemination [89].

The purpose of this research is ultimately to investigate the usability concerns of an existing decision aid tool built for industry by members of academia – specifically the ACAP assessment tool developed during Part 1 – to determine recommendations for improving the usability of similarly developed tools. It is important to note that the ACAP assessment tool is an innovation management decision aid and not directly an engineering design decision aid tool, however the recommendations that will be made will not be tool or domain specific.

At the end of the usability studies done while attending GINP, the functionality of the tool was proven however its stand-alone usability was still a concern. Outside of functionality problems, various usability concerns were identified during Part 1. One particular area of interest which was identified was the effect of information conciseness on the tool's usability. All five non-expert users complained that using the tool required a lot of reading and a lot of information to be processed. One user in particular chose to skim through this information with little to no level of understanding ultimately resulting in not being able to get anything meaningful out of her results. *It is my initial prediction that the lack of conciseness in the tool caused users to spend more time while trying to understand*

the process resulting in them being more likely to make errors or not be able to complete the tasks in the allotted time.

To meaningfully consider usability, literature was used to identify 5 attributes of usability: (1) efficiency, (2) effectiveness, (3) satisfaction, (4) learnability, and (5) usefulness. These attributes which will be further discussed in Chapter 7, the initial predictions which were made, combined with the aforementioned objectives of the research was used to develop the following initial research questions:

RQ1: How does conciseness affect the usability of a decision aid tool in terms of its efficiency, effectiveness, satisfaction, learnability, and usefulness?

RQ2: What recommendations can be made to improve the usability of decision aid tools developed within academia?

After conducting the first four studies in Part 2, it was found that other factors should be considered beyond conciseness. The first of these additional factors was related to understandability of instructions when read by non-native speakers. It had been noticed during Part 1 that both of the non-native French speakers who participated in the studies identified that they felt they were struggling to understand the tool due it being in a foreign language for them. However, it was believed that these issues would not appear in the English study versions. It was believed that any non-native speakers would have a considerably higher foreign language proficiency at Clemson University compared to those who had participated from GINP. Although the language proficiency is most likely still higher for all of the participants from Clemson, the results of the first four English studies suggested that these usability problems in this area still existed. It was also identified in these first four studies that at least one participant seemed to have exceptionally high levels

of frustration and seemed to be exerting a lot of effort into learning the process of using the tool. It was believed that this perceived workload may have affected the learnability and effectiveness of the tool. *It was predicted that more concise instructions would be make it easier for non-native speakers to effectively use instructions for unfamiliar processes. It was also predicted that users with would experience lower levels of workload if given the concise tool.* These predictions were used to craft two additional retrospective research questions:

RQ3: How does conciseness affect the usability of instructions specific to non-native speakers?

RQ4: How does conciseness affect the perceived workload of participants?

An explanation of the research method which was developed to address these questions will be explained in Chapter 7. The findings from the studies which were conducted will be analyzed and discussed in Chapter 8. The recommendations made based off these findings is included in 8.4. Finally, a summary of the conclusions and future work will be included in Chapter 10.

Chapter 7. Research Method

With these two areas of interest in mind, the tool was translated into English and a think-aloud study protocol was developed. Two English versions of the tool were created to investigate the effects of conciseness which will be henceforth referred to as (1) the non-concise version and (2) the concise version.

7.1 Translation from French to English

As the tool developed and tested during Part 1 of this research was written in French, it had to first be translated into English before the start of Part 2 for further investigation at Clemson University. As previously stated, some content from the French version of the tool had been previously translated into English by one of the tool's earlier developers. This was used to verify the accuracy of my English translation of the tool's content as well as my faithfulness to its original meaning. My final translation has not been fully reviewed by an English-fluent, native-French speaker to verify this. However, to verify the normalcy of the English translation another English speaker was asked to review it. Text where information may have been lost in translation was identified and then adjusted to ensure the meaning was comparable between the original and the translation. The most notable of these adjustments occurred within the ranking sheet and are summarized in Table 7-1.

Table 7-1. Notable translation changes

French	*English*	*Explanation*[2]
Classement	Ranking	The word "classement" in French translates to either "ranking," "classifying" or "grading." It generally means to evaluate something by sorting it into a list or series of categories.
Niveau	Rank	The word "niveau" in French normally translates to "level" in English however it shares the same meaning as the word "rank" when referring to a ranking procedure (or "classement" in French). The French word "rang" more directly translates to "rank" however it is less commonly used in this context.
Intervalle	Difference between ranks	The French word "intervalle" generally refers to "the distance between two things." It can also be translated as "gap." It most directly translates to the word "interval" in English which technically shares the same meaning, however this word sounds unnatural within the context of ranking.
Vous, votre	Your organization, your organization's	"Vous" is both the formal and plural versions of the word for "you" in French. "You" in English, though it can refer to a group of "you," it by itself is by default singular. As a result, a direct translation of "vous" as "you" becomes very ambiguous. In an effort to lessen this ambiguity "vous" was replaced with "your organization" throughout. Similarly, "votre" is both formal and can refer to the plural of "yours." This was translated as "your organization's."

[2] https://www.collinsdictionary.com/dictionary/french-english/

https://dictionary.cambridge.org/dictionary/french-english/

https://www.linguee.com/english-french/

7.2 Conciseness

After the actor ACAP assessment developed in Part 1 had been directly translated into English, it was modified to create a more concise version. An increase in conciseness refers to extraneous words, phrases, clauses, and sentences being eliminated without sacrificing clarity or appropriate detail [90]. In other words, conciseness is the avoidance of "wordiness." Contributors to conciseness include repeat modifiers to words (Ex: completely finished vs finished) as well as unneeded expletives, pronouns, and relative adjectives (There are many people who… vs Many people…) [90]. It also involves eliminating redundancy, using an active voice, getting rid of introductory or pretentious phrases (It is the case that…), avoiding overuse of intensifiers (very, best) [90]. Using these methods for creating conciseness, the textual information within the first 4 sheets of the workbook was reworked.

More details into the structure of the ACAP tool that was developed are included in §3.3.1 however a summary is included in Figure 7-1 below. This structure and functionality of the tool was kept the same for both the concise and non-concise versions.

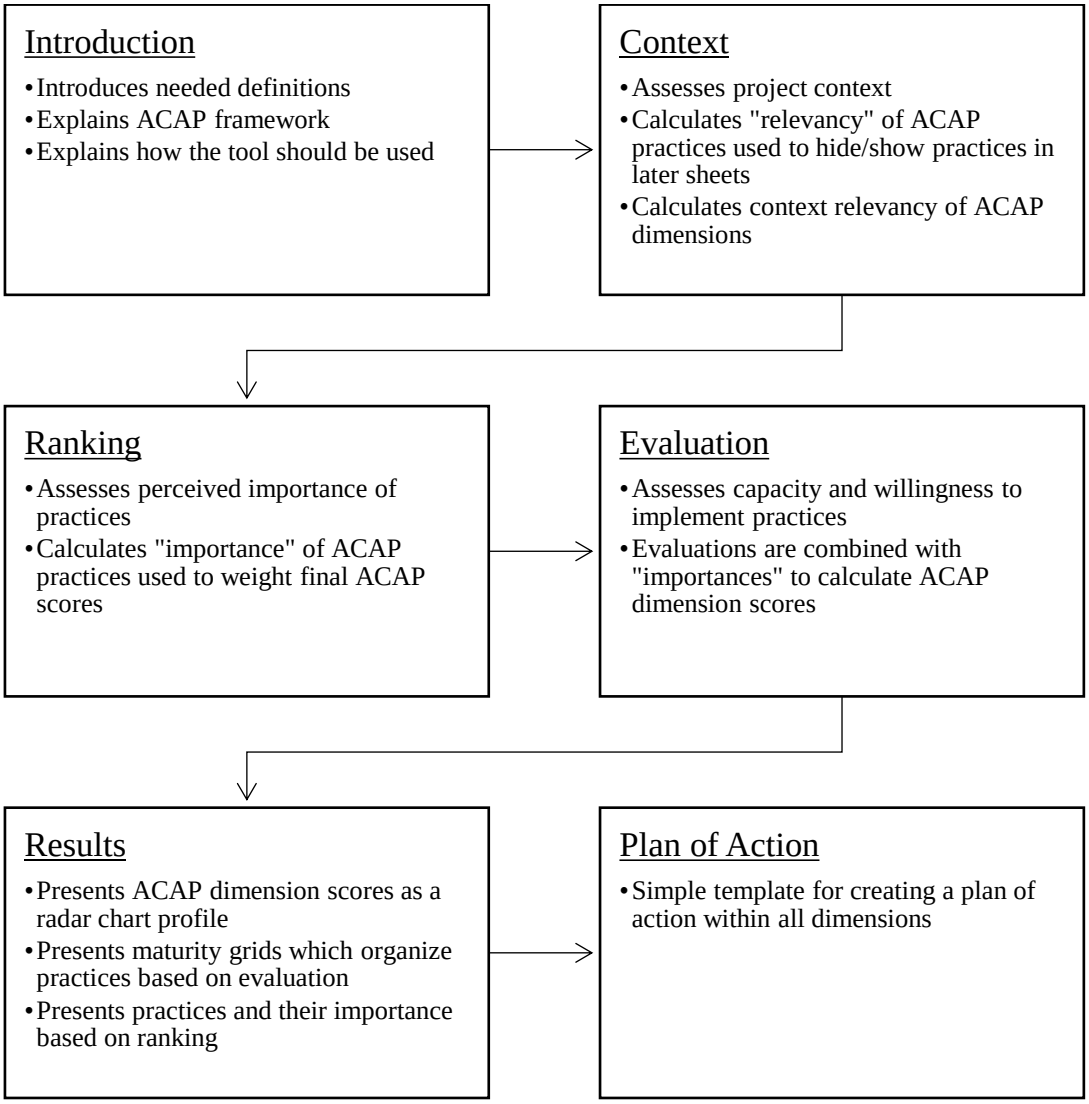


Figure 7-1. Summary of sheets within ACAP assessment tool

7.2.1 Introduction Sheet

The same information was presented at differing levels of conciseness in both versions of the tool. Effort was made to keep the order of that information and amount of detail the same between versions. There is one notable exception to this rule. During the usability studies from Part 1, at least 2 users verbally complained that the schema seemed repetitive. It was found during testing that users would often read the details shown within the first phase of the schema, begin reading the second phase, comment that they thought these were the same, and then would stop reading the schema all together. No users ever felt the need to refer back to this schema later in the study. It was believed that this schema could be restructured so that only the needed information was being conveyed in a way which relied upon fewer words. These figures from the non-concise and concise versions of tool are included in Figure 7-2 and Figure 7-3 respectively.

The primary changes that were made between these schemas were in the elimination of the description for each dimension within each phase. It was my belief that the headers alone were adequately informative and that the practices that would appear within each dimension later in the tool would provide the detailed understanding needed for a fuller interpretation. Both figures explain that the acquisition, assimilation, and application of external knowledge occur within each of the three project phases and that this process is cyclical. In Part 1, the dimensions had been referred to as "thématiques," or in English "thematics[3]." Though it is an unusual word in American English it is recognized by the

[3] https://en.oxforddictionaries.com/definition/thematic

Oxford dictionary. This word was kept within the non-concise version of the tool, however it was changed to “dimension” throughout the concise tool.

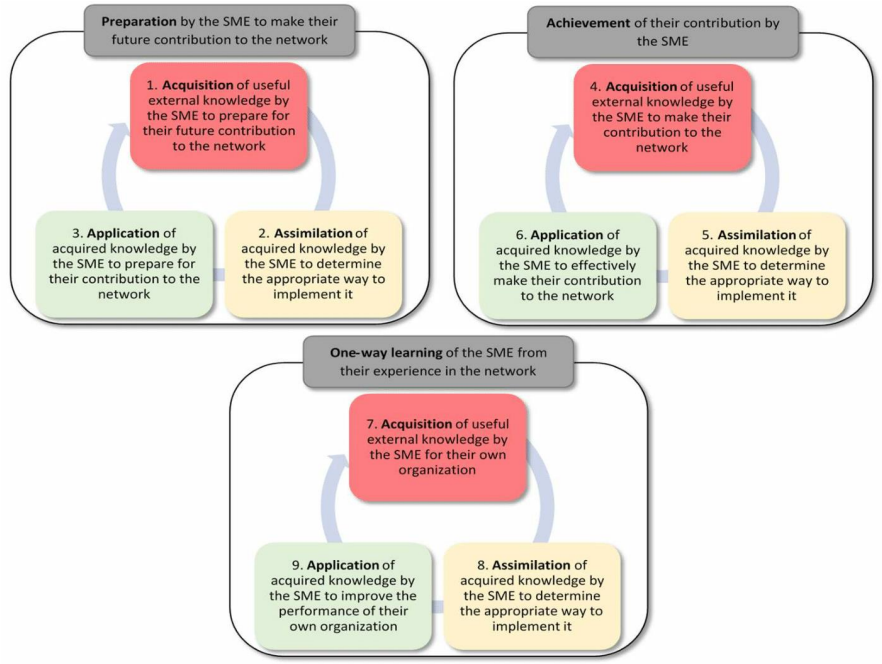


Figure 7-2. ACAP schema from non-concise version

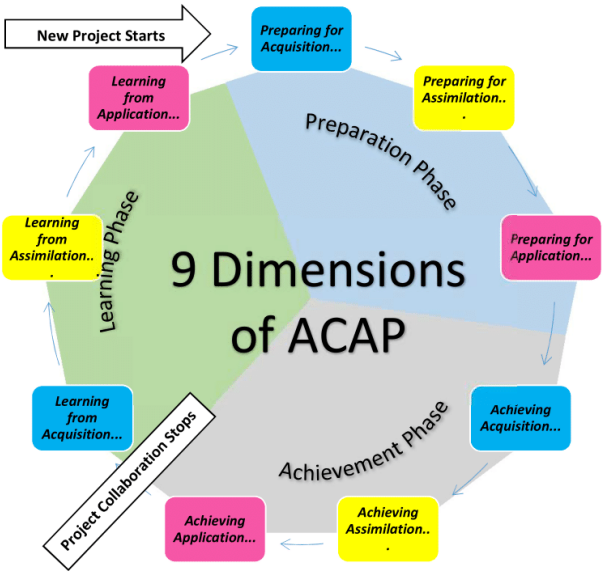


Figure 7-3. ACAP schema from concise version

7.2.2 Context Sheet

The only changes made to the context sheet were to the header and instructions as shown in Figure 7-4 and Figure 7-5. The context statements remain the same for both tools are included in Appendix A for reference.

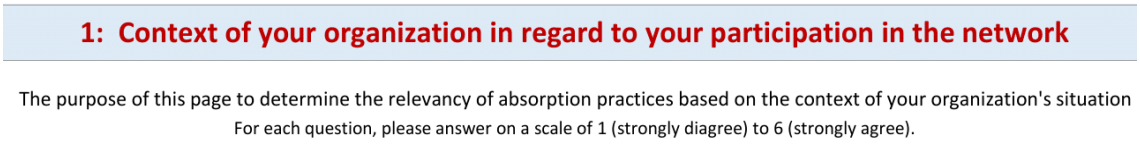


Figure 7-4. Non-concise context header and instructions

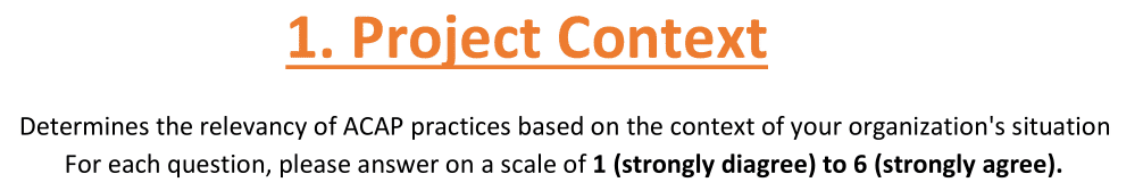


Figure 7-5. Concise context header and instructions

7.2.3 Ranking Sheet

More significant changes were made to the ranking sheet between the two versions of the tool. As can be seen from Figure 7-6, the non-concise ranking instructions are a lot of text. These instructions include four parts: (1) list of recommendation on how to avoid common errors, (2) textual explanation of the process, (3) a more visual summary of the same information, and (4) detailed dimension headers.

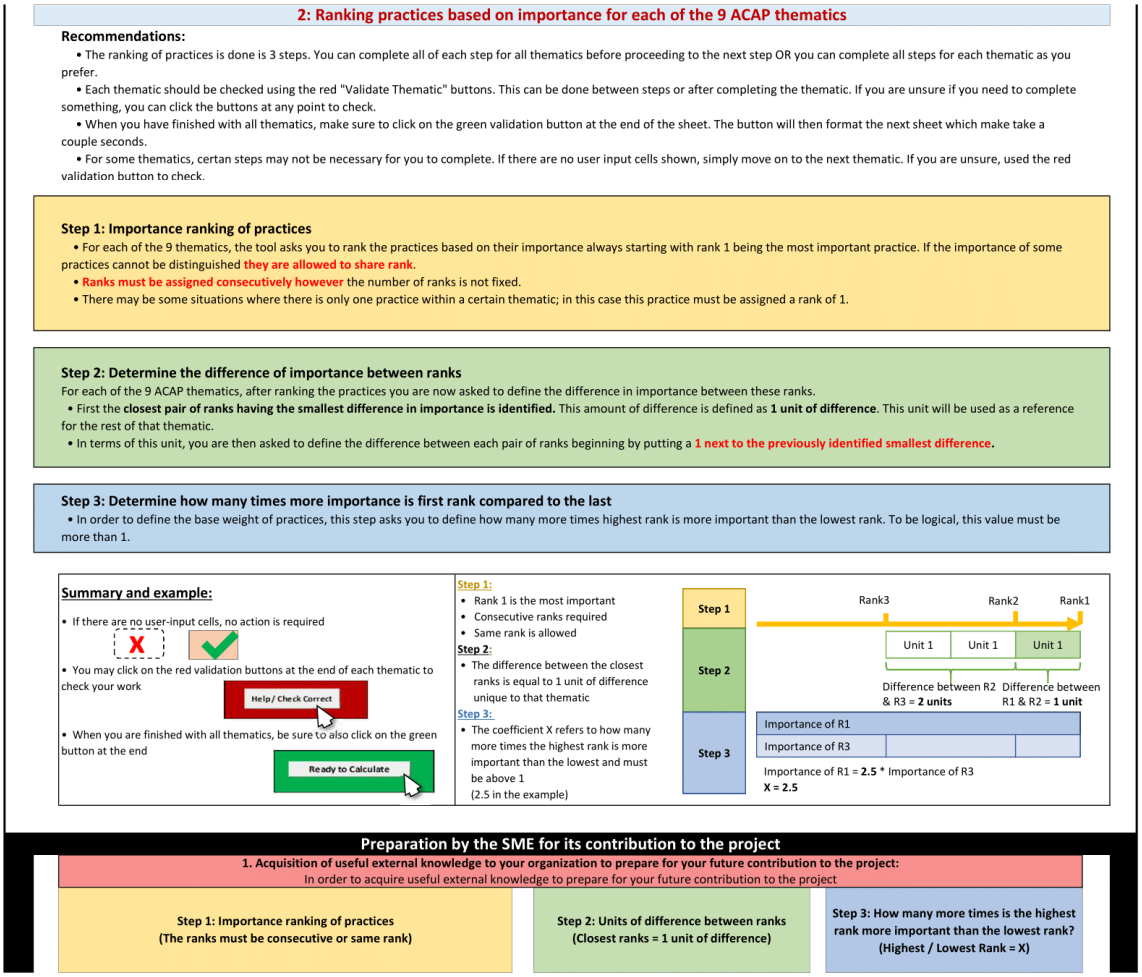


Figure 7-6. Non-concise ranking instructions

In order to create the concise version, the first two parts of these instructions were entirely eliminated to avoid redundancy. Slight adjustments were made to the visual summary and headers to still provide the same information but with fewer words. Similar to the schema from the introduction, the full explanations of the phases and dimensions were also reduced to just their headers.

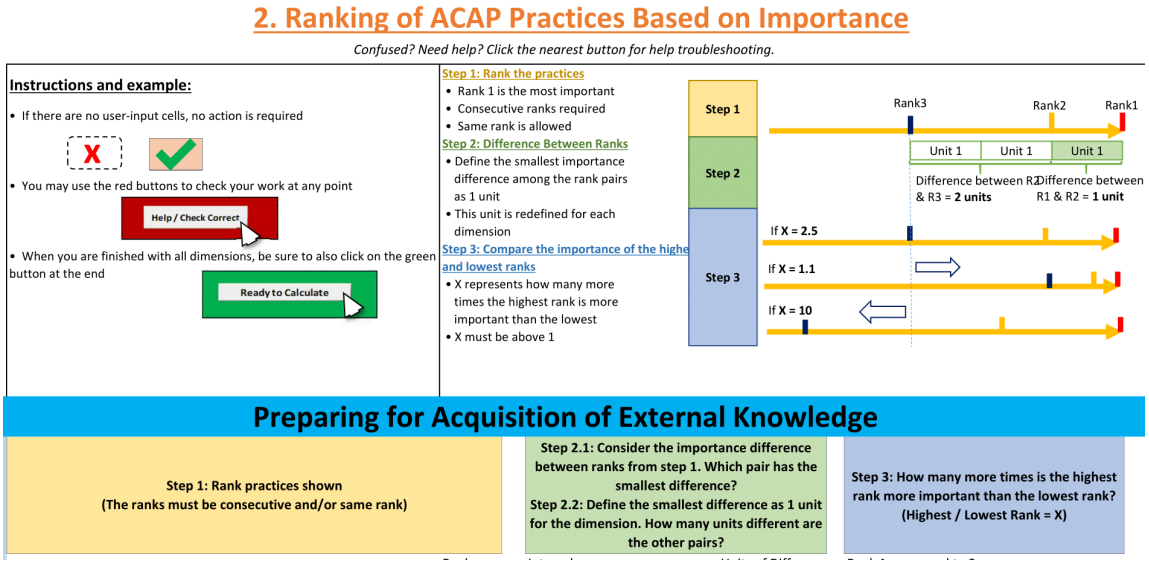


Figure 7-7. Concise ranking instructions

The practices for both versions of the tool remain identical between tools and are included for reference in Appendix A.

7.2.4 Evaluation Sheet

The instructions on the evaluation sheet were similarly cut in half by eliminating redundant statements covered elsewhere in the tool instructions. The headers were reduced similar to previous sections as shown in Figure 7-8 and Figure 7-9. The two of the willingness scale descriptions were reworded slightly for conciseness though they kept the same meaning.

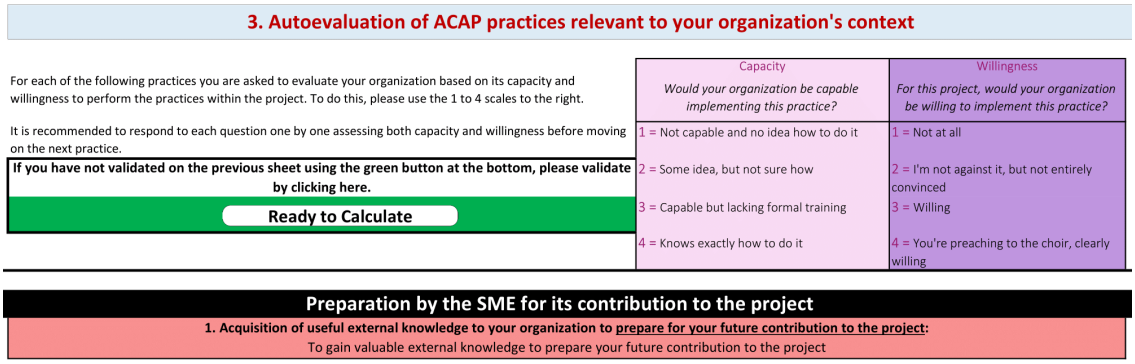


Figure 7-8. Non-concise evaluation instructions

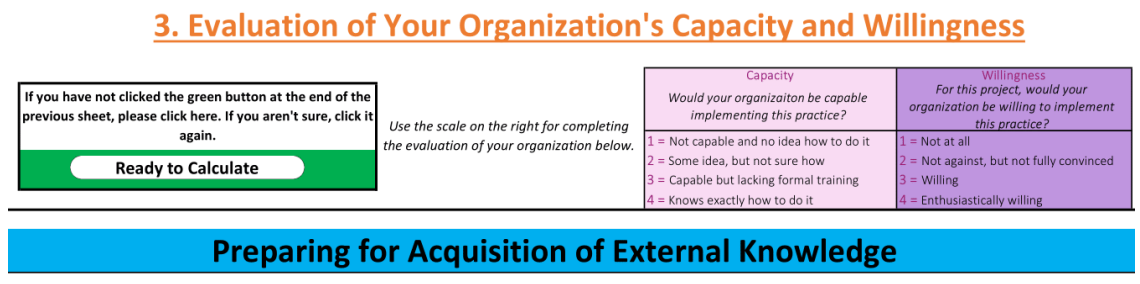


Figure 7-9. Concise evaluation instructions

7.2.5 Results Sheet

Changing the headers to match the rest of the work book and using the word "dimension" instead of "thematic" were the only significant changes made to the results sheet. The plan of action sheet was never used during the studies however it did remain the same between tools.

7.3 Development of Think-Aloud Study Protocol

The script that had been developed for the usability tests in Part 1 as described in 3.4 of this work was first translated into English and used in a Pilot study. As the objective of the study was no longer on making iterative improvements to the tool, the script was then modified to better fit the research goals of Part 2. The final script which was used is included in Appendix B.

The introduction of this script was modified to accommodate IRB requirements for how the study should be introduced. Initial questions related to the network ACAP assessment tool of Part 2 were eliminated. The remaining questions focus on identifying a current research project of the participant which can be used as part of their scenario, similar to what was done for Part 1.

The initial review of the tool of the tool remains identical to what was used during Part 1.

The scenario development script was modified slightly to be applicable to graduate researchers at Clemson University rather than the GSCOP laboratory in Grenoble, France. It otherwise remains the same.

The introduction to using the tool was not significantly modified, however changes were made to the task protocol. For the first four participants, which were notably not given the NASA TLX workload assessment, the four tasks were identical to those which had been used for the usability studies from Part 1. The user was simply prompted to read and/or complete the introduction, context, ranking, and evaluation sheets. As our objective for these studies was to investigate how engineers use decision aid tools, the results task was modified to include a more prompted think-aloud interpretation of these results.

The objective of these questions was to obtain results interpretations which could be more directly compared between participants in hopes of learning more about the participants similarities and differences in how they process the output of a decision aid. In order to avoid leading questions, the user is asked both to identify something positive (a strength) and something negative (a weakness) from their results. To gauge how well they are able to relate their understanding of their results back to their projects, they are then asked to identify what they feel is the cause of this strength or weakness. Participants are then asked to determine an improvement action that they as their organization can make as well as they as themselves. This was done to explore how well the participant was able to think of themselves as their organization rather than simply as an individual when using the tool, but also to determine how well they were able to determine improvement actions based on their results.

After this interpretation is complete, a debriefing interview is given. The aims of these questions are to capture their honest opinions and attitudes about the tool now that they are finished. It is expected that since this debrief is a face-to-face interview and that most of

my participants would know me beforehand, response bias is more than expected. Care was taken in the way questions were asked to control this bias as much as possible.

Response bias refers to the systematic tendency of people to respond to questions on some basis other than what the question is designed to measure [91]. Social desirability causes people to respond in a way which makes them look good and gives a good impression. To avoid this, most questions were framed so that they evaluated the performance of the tool and not on the direct performance of the user. A notable exception to this was the first question regarding the level of difficulty to figure out the tool. To account for this bias, users are then asked to identify both the most difficult and the easiest parts of the tool allowing them to focus their responses back again on the performance of the tool rather than themselves.

Care was taken to phrase questions in a non-leading way to avoid acquiescence. Bias from acquiescence refers to the tendency of people to agree rather than disagree with propositions.

Both the results interpretation interview and debriefing questions were developed to elicit responses relating to various attributes of usability based on literature and ISO 9241-11 which are included in Table 7-2 [92–94].

Table 7-2. Common attributes of usability

Attribute	*Definition*
Efficiency	How much does the outcome justify the cost?
Effectiveness	How successful were users in achieving tasks?
Satisfaction	What attitude does the user have towards the tool?
Learnability	How easy was it to figure out functionalities?
Usefulness	How much value does it produce?

The results interpretation and debrief questions are intentionally phrased in a vague way to allow participants to respond with depth allowing for triangulation between usability attributes. The primary attributes which each question is designed to elicit evidence of is summarized in Table 7-3.

Table 7-3. Usability attributes of results interpretation and debrief questions

	Question	Relevant Attributes
Results Interpretation	Please identify an area of strength. What do you think is the cause of this strength?	Effectiveness
	Please identify an area of weakness. What do you think is the cause of this weakness?	Effectiveness
	What action would you recommend that your organization take to improve in areas where it may be weak?	Effectiveness
	What action would you recommend that you take to improve in areas where you or your organization may be weak?	Effectiveness
Debrief	Overall, how easy or difficult was it to figure out how to use the tool?	Learnability and satisfaction
	Which parts of the tool were the most difficult and why?	Learnability and satisfaction
	Which were the easiest and why?	Learnability and satisfaction
	How do you perceive the amount of effort needed to use the tool?	Efficiency and satisfaction
	How do you perceive the overall usefulness of the tool?	Usefulness, effectiveness, and satisfaction
	How do you perceive the amount of time needed to use the tool?	Efficiency and satisfaction
	If you used the tool for a future collaborative project, when during the project would you use it and how?	Learnability, satisfaction, usefulness
	What recommendations would you offer an organization considering using this tool?	Effectiveness, satisfaction, usefulness
	What characteristics would an organization need to get the maximum benefit out of using the tool?	Effectiveness
	What would you say are the most important things that you learned from using the tool today?	Learnability, usefulness

After completing the think-aloud studies for the first four participants it was believed that conciseness may not be having the positive effect on usability that was originally predicted. It was suspected that conciseness may have been increasing the amount of effort required to understand the task rather than reduce it as had been predicted. To further investigate this as well as other measures of workload, the NASA Task Load Index (NASA TLX) was implemented.

Workload within the NASA TLX refers to the cost of accomplishing mission requirements for a human operator [95]. NASA TLX evaluates perceived workload by using a weighted average approach consisting of six subscales: (1) mental demand, (2) physical demand, (3) temporal demand, (4) frustration, (5) effort, and (6) performance which are shown in Table 7-4 [95].

Table 7-4. NASA TLX workload definitions [95]

Title	*Endpoints*	*Descriptions*
Mental Demand	Low/High	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low/High	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration Level	Low/High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

For a given task, the NASA TLX first asks participants to rate each of these workload subscales on a series of number lines as shown in Figure 7-10.

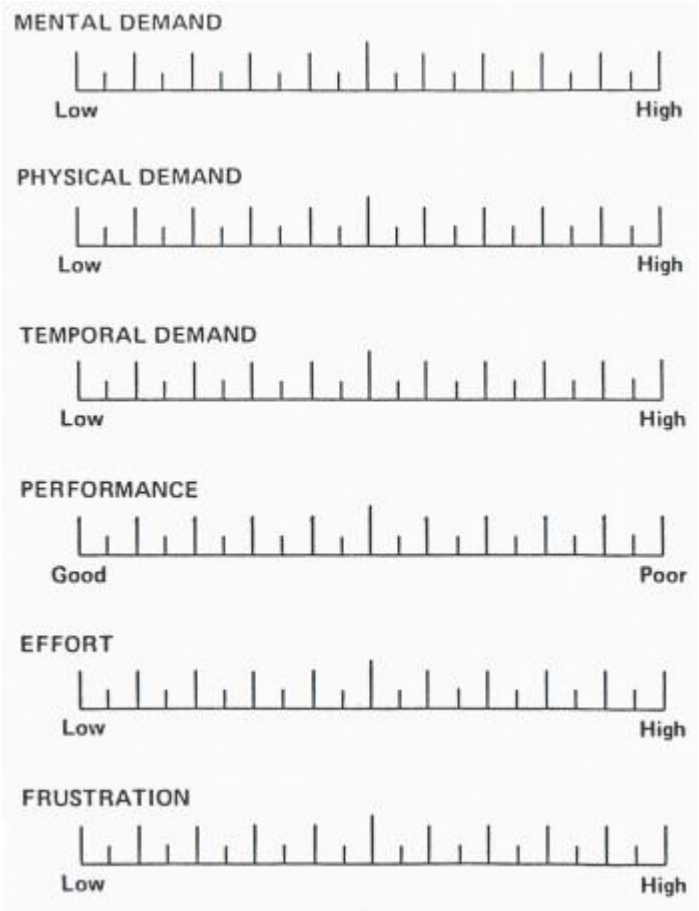


Figure 7-10. NASA TLX Rating Sheet [96]

Next, pairs of these scale titles are listed on a series of cards. For each pair, the participant is asked to circle the scale title that represent the more important contributor to workload for the specific task(s) that they performed. These are these tallied for each workload source and used as a weighted multiplier for that respective rating. An overall workload score can then be calculated. Further detail into these calculations will be included in §8.4.

All participants after the first four, were given the NASA TLX after both the introduction task and again after the results task. The introduction task was modified to how it is shown in Appendix B and now asks participants to read for understanding with the expectation that they will need to provide a summary afterwards. After providing the summary they are prompted to complete the NASA TLX for that task. Similarly, after completing the results they are tasked with completing a second NASA TLX survey which will pertain to the context through results interpretation tasks. The introduction workload will act as a baseline for comparison with the workload needed for the rest of the study.

7.4 Selection of Participants

A list of current Clemson Engineering Design Applications and Research (CEDAR) students was made and used to randomly select participants. This pool of students was chosen due to their accessibility but were also thought to be the most comparable to users from the French studies. All participants both in the US and in France were graduate students working on research projects who had taken courses in engineering design. Both native and non-native speakers were allowed in both studies. Based on suggested minimum English-language competency requirements for admission into the Clemson engineering graduate program, all non-native English participants are assumed to have at least an upper intermediate to high English language competency according to the TOEFL exam. All non-native French speakers participating in the French studies were known to have comparable advanced or master level French language competency based on the DELF exam.

A total of 12 studies were conducted in English following a nearly identical protocol. Alternating participants were given either the concise or non-concise version of the tool

based on the order of their participation. Three out of the twelve participants were female, one of which was selected to use the concise version of the tool. Six out of the twelve participants were non-native English speakers. Three users had some prior knowledge about the meaning of Absorptive Capacity (ACAP), two had pretty good prior knowledge about the meaning of a collaborative innovation network (CIN), however no participants were aware of having ever used Simos' method. A summary of the participants and their basic profiles are included in Table 7-5.

Table 7-5. Think-aloud participant profiles

Name	*Date*	*Tool*	*TLX*	*English*	*ACAP*	*CIN*	*Simos*
Azelma	9/25	Concise	No	Non-Native	Some	Good	None
Baptistine	9/26	Concise	No	Non-Native	Some	None	None
Cosette	9/27	Concise	Yes	Native	Some	None	None
Dahlia	9/28	Concise	Yes	Native	None	Good	None
Esmeralda	10/2	Concise	Yes	Non-Native	None	None	None
Fantine	10/3	Concise	Yes	Native	None	None	None
Juliette	9/26	Non-Concise	No	Native	None	None	None
Léopoldine	9/26	Non-Concise	No	Non-Native	None	None	None
Magnon	9/28	Non-Concise	Yes	Native	None	None	None
Simplice	10/4	Non-Concise	Yes	Non-Native	None	None	None
Toussaint	10/2	Non-Concise	Yes	Native	None	None	None
Zéphine	10/3	Non-Concise	Yes	Non-Native	None	Some	None

During each participants study, a scenario was developed based on one of their current research projects. The scenarios of participants' whose projects did not include an external actor such as researchers at another university or collaborators at an industry partner were modified for the sake of the study so that that did. In their scenarios, all participants were acting as their Clemson University research team when using the tool. The only exception to this was Dahlia who for some reason chose to represent her industry partner and have her research team at Clemson act as her partner organization. As can be seen from Table 7-6, most of the participants who had been given the concise tool indicated that they were in early phases of their project, whereas most of the ones given the non-concise tool were closer to the end of their projects. The project lengths also happen to be a bit longer for many of the participants given the non-concise tool than those given the concise tool. Also noticeable, more of the participants given the non-concise tool also happened to be working on non-collaborative projects which was why many of their scenarios had to be modified.

Table 7-6. Think-aloud participant scenarios

Name	*Date*	*Tool*	*Research*	*Scenario*	*Actors*	*Phase*	*Project Length*
Azelma	9/25	Concise	PhD	Same	2 Universities	Near End	2 years
Baptistine	9/26	Concise	Master's	Same	2 Universities 1 Industry	Early	2 semesters
Cosette	9/27	Concise	Master's	Modified	1 University 1 Government Agency	Early	2 semesters
Dahlia	9/28	Concise	Master's	Same	1 University 1 Industry *(Represented industry actor)*	Early	1 year
Esmeralda	10/2	Concise	Master's	Modified	1 University 1 Industry	Early	1 semester
Fantine	10/3	Concise	Master's	Same	2 Universities 1 Industry	Early	1 year
Juliette	9/26	Non-Concise	PhD	Modified	2 Universities	Near End	5 years
Léopoldine	9/26	Non-Concise	PhD	Modified	1 University 1 Industry	Near End	3 years
Magnon	9/28	Non-Concise	Master's	Same	1 University 1 Industry	Near End	1.5 years
Simplice	10/4	Non-Concise	Master's	Modified	1 University 1 Industry	Early	1 year
Toussaint	10/2	Non-Concise	Master's	Modified	1 University 1 Industry	Near End	1 year
Zéphine	10/3	Non-Concise	PhD	Modified	1 University 1 Industry	Near End	5 years

Table 7-7 below includes the project context information that participants gave based on their scenarios. Statements with higher standard deviations in their responses are highlighted in red while lower standard deviations are highlighted in green. As can be seen, the response distributions are the closest together for the statement regarding technical coordination on the project, which makes sense considering all participants and their teams would be expected to the ones developing the innovative technology within their project. The most distributed statement was about the exclusivity in the resultant intellectual property. This was at least partly due to the fact that many participants were not certain about who would own what parts of the intellectual property in their scenario or how to give a numerical level of agreement to this statement. Notably, Baptistine and Fantine both used the same project as their scenario and generally answered in a similar way about most statements. The most notably exception to this was statement about the project being motivated by financial profits which Baptistine rated low and Fantine rated somewhat high.

Table 7-7. Project context average values

Avg.	*Std. Dev.*	*Context Statement*	**Azelma**	**Baptistine**	**Cosette**	**Dahlia**	**Esmeralda**	**Fantine**	**Juliette**	**Léopoldine**	**Magnon**	**Simplice**	**Toussaint**	**Zéphine**
4.5	1.31	The level of technological intensity is high (new science being used to enhance industry)	5	6	2	3	4	5	3	5	4	6	5	6
4.4	1.24	The frequency of innovation is high	5	3	5	2	6	6	5	3	5	5	4	4
3.8	1.34	The level of concurrence/competition is high	3	3	6	4	3	5	3	5	2	5	5	2
4.1	1.93	To acquire knowledge about a component or solution outside of a particular application (technical characteristics, etc.)	4	5	2	6	1	6	6	3	6	1	5	4
4.8	1.85	To learn how to use a component or solution specifically for your contribution to the project (specific to this application)	5	6	1	6	1	5	6	6	5	6	5	6
2.7	1.83	Is or will be involved in interactions with the target market of the project	5	2	4	6	1	2	1	2	5	1	2	1
5	1.35	Is or will be involved in the management of the project	6	5	3	6	6	3	4	6	6	3	6	6
5.4	0.79	Is or will be involved in the technical coordination of the project	6	5	6	5	5	4	4	6	6	6	6	6
3.5	2.24	Has or will have exclusive rights to the resultant intellectual property (As the number of co-owners of these rights increases, the exclusivity decreases)	1	2	1	6	6	1	1	4	6	5	3	6
2.3	1.61	Generate significant financial profits	3	1	1	6	2	4	1	1	2	2	1	4
4.4	1.51	Acquire new useful knowledge for your organization outside of this project	5	3	4	6	4	5	1	6	6	5	5	3
2.1	1.51	Intitiate strategic internal changes	1	2	1	6	3	3	1	1	1	3	1	2
5.2	1.75	Knowledge bases which are very different from your organization	6	6	5	6	6	6	6	6	6	6	1	2
4.9	1.44	Organizational structures and/or work cultures different from your organization	4	5	6	6	6	5	1	6	6	5	5	4
3.9	1	Areas of interest or competencies similar to your organization	3	5	4	4	3	5	4	2	4	3	5	5
2.8	1.48	Commercial orientation/direction similar to your organization	5	3	2	3	1	2	6	1	2	2	3	3

Chapter 8. Think-Aloud Study Results

The results are structured around the aforementioned usability attributes. Efficiency, satisfaction, learnability, and usefulness will first be characterized in §8.2 based off of the detailed summaries and transcripts included in Appendix D. Effectiveness of the tool will later be considered based on what participants were able to identify within their results interpretation in §8.3.1, the time needed to complete the task in §8.3.2, and the error messages received during the study in §8.3.3. The effects of workload will be discussed in in §8.4. Discussions of the meanings of these results will be included at the end of each section.

8.1 Expectations of Study

During the study the participant is asked to complete 5 tasks each corresponding to a sheet within the workbook: (1) review the introduction of the tool, (2) give project context, (3) rank relevant practices, (4) evaluate the actor on these relevant practices, and then (5) interpret the results. It is expected that participants may identify minor typos or may not fully understand certain aspects of the tool but that they should be able to successfully complete the tasks regardless. They may ask questions at various points during the study which I will more often than not choose not to give answers to. For most things they are expected to be able to use parts of the tool to figure out the answer.

The introduction does not require any inputs from the participant but does explain what the tool is and how it works. The project context task asks the participant to indicate their level of agreement with a list of statements using a 6-point scale. These responses are used to determine the relevancy of practices which will be used later in the tool. No significant

errors are expected during this time and users are expected to find this task mostly straight forward.

Next, the user is tasked with completing a 3-step ranking process. Based on the usability studies conducted in France, this process posed the most difficulty for participants to successfully complete without intervention compared to the other tasks. It is expected that participants will make errors before they completely understand the process and that they will need to read the instructions multiple times. It is expected that the error messages will be helpful in troubleshooting errors and building user confidence in their responses.

Participants will then evaluate the organization they are representing using two 4-point scales. A description of the scale stays frozen at the top of their screen which may help or hurt them. This process is not otherwise expected to cause many problems for the participant.

Finally, the participants are asked to interpret the results. It is expected that participants may find parts of the results easier to interpret than others or may favor explaining what they learned from doing the process rather than what they learned from the final output. It is also expected that most participants will initially respond in a positive way when asked about their perceptions of the tool in an effort to be kind, however it is expected that they will elaborate upon their perceptions in a more honest way if given time to do so.

8.2 Efficiency, Satisfaction, Learnability, and Usefulness Participant Characterizations

The following section will characterize the tool's efficiency, level of satisfaction, learnability, and usefulness based on verbalized perceptions of users and their actions

during each study to analyze its meaning. To ensure thoroughness, evidence within the detailed summaries and transcripts which appeared to contribute to particular usability attributes was first highlighted following the illustrations in Table 8-1. An analysis of effectiveness will be further explained later in §8.3.

It is important to note that usability attributes are by no means independent [92]. It is very possible to interpret the same action as belonging to multiple usability attributes; the highlighting in Appendix D will focus on the significant evidence only and will simply be used to help characterize the usability for use in the following tables.

Table 8-1. Highlighting scheme for identifying characteristic usability attributes within detailed summaries

Attribute	*Definition*
Efficiency	How much does the outcome justify the cost?
Effectiveness	How successful were users in achieving tasks?
Satisfaction	What attitude does the user have towards the tool?
Learnability	How easy was it to figure out functionalities?
Usefulness	How much value does it produce?

Table 8-2 and Table 8-3 will summarize the efficiency perceptions of participants for the concise and non-concise tools respectively. Table 8-4 and Table 8-5 will similarly focus on satisfaction, Table 8-6 and Table 8-7 on learnability, and Table 8-8 and Table 8-9 on usefulness. A discussion considering the meanings of these tables together will be included at the end of this section.

Table 8-2. Efficiency based on concise tool participants

	Characteristic Quote	*Summary of Characterization*
Azelma	"If an organization was investing money into this they would be willing to go through this ordeal. If they deem it to be helpful."	**Somewhat efficient -** She appears to believe that the tool would only be worth it in some contexts but that an organization could decide for themselves.
Baptistine*	"If it wasn't for the purpose of this I probably would have given up immediately because it's just not worth the time to spend this long on figuring it out."	**Not efficient –** Though Baptistine felt like there was some value in the tool, she did not feel that the time needed to get this value was justifiable.
Cosette	"I know people probably wouldn't like to spend an hour and a half, two hours doing this as they are busy working. So if you have the time to do it, it might be worth it. But I know for many people it's probably not ideal."	**Not efficient –** Cosette believed that the amount of time needed to use the tool would be prohibitive for most people. She also felt that the tool takes more time that it needs to without some sort of training beforehand.
Dahlia	"So I definitely see the tool as taking too long to want to use."	**Not efficient –** Though Dahlia suggested that the tool could be broken up into shorter time segments, she generally felt that the time needed was too much to make using the tool worth it in a single 2 hour block.
Esmeralda*	"Is it going to take us 5 hours for us to do this thing?"	**Not efficient –** Esmeralda was noticeably critical of the usefulness of the tool early on and would frequently complained about the time needed to use it. She wound up quitting the study prior to reaching the end, therefore it is believed she found the tool not worth the time needed.
Fantine	"I definitely could do it faster if I did it again in another context. But it was an hour which is a pretty long time especially if you're exerting effort in the interpretation"	**Not efficient –** Fantine generally found that her results were not useful and complained about the time required and the amount of effort.

Table 8-3. Efficiency based on non-concise tool participants

	Characteristic Quote	*Summary of Characterization*
Juliette	"It's a very reasonable amount of time to help make the big decisions if this is used for something sufficiently complicated requiring that that decision should be a slow one."	**Efficient –** Though Juliette found usefulness to largely be project context specific, for the more complicated decisions she felt the time would be justifiable.
Léopoldine	"So this is a onetime thing that take one and a half hours, it's good enough. It justifies itself."	**Efficient –** Léopoldine felt that the time was justifiable and noted that it helped her consider criteria she had not before.
Magnon	"I felt like it was quite a bit of time for what came out."	**Not efficient –** Magnon did not feel that the usefulness of the results justified the time spent.
Simplice	"I think it's not much time in return for the results you get."	**Efficient –** Simplice felt that the results justified the time spent.
Toussaint	"It took about an hour, right? Hour and a half maybe? Which out of a day, if this helps your SME's abilities to, or identify your weaknesses and improve upon them"	**Efficient –** Toussaint felt that weaknesses and strengths that the tool identified justified the time needed.
Zéphine*	"Putting the ranking aside… it's not so time intensive. But the ranking, I think took a lot of time for me."	**Somewhat efficient –** Zéphine felt that the time needed was justifiable with the exception of the ranking process due to the usefulness of the results.

Table 8-4. Satisfaction based on concise tool participants

	Characteristic Quote	*Summary of Characterization*
Azelma	"It was long but it was okay" "It was okay, it was not too bad. Except the results thing."	**Mostly satisfied -** After most critiques she gave, Azelma would usually indicate that she found this to be acceptable. The notable exception to this was the results page because she struggled to interpret the meanings of the dimensions.
Baptistine*	"It's just way too colorful." "And the scales, it should be flipped in my mind." "The figure, it doesn't portray what is should portray."	**Unsatisfied -** Baptistine would often complain about the colors when she was getting confused. She felt that the scales were all inverted and that the instructions were not clear. She also complained about the length of various parts of the tool.
Cosette	"It was a little too hard to figure out how to use it I guess."	**Mostly unsatisfied –** Cosette ultimately found that the tool was too difficult to know for sure if she was doing it right. Though satisfied with the color coding and organization, she complained about the length and disagreed with some of the information presented.
Dahlia	"Wow, there are a lot of different sections to rank." "It kind of became painstaking half way through."	**Unsatisfied –** Dahlia was generally unsatisfied with the formatting, length, and vocabulary used in the tool. She took particular issue with the managerial language used throughout the tool.
Esmeralda*	"But what I'm trying to get at is sometimes if you don't want to go that deep with people. Not everyone is that deep. Many people that go that deep are problems."	**Unsatisfied –** She was generally unsatisfied with the language used, time, or depth of thought that she felt the tool required.
Fantine	"I think that if there was another way of translating what is on the results tab to "top strengths/top weaknesses/quickest wins/may need outside resources for" a breakdown like that, I think it would be more useful."	**Somewhat unsatisfied –** Though entirely unsatisfied with the results, she had indicated satisfaction with the process of getting the results.

Table 8-5. Satisfaction based on non-concise tool participants

	Characteristic Quote	*Summary of Characterization*
Juliette	"And I didn't have enough context to know what my answers mean to make good judgments." "I would not trust the results."	**Unsatisfied –** Juliette was critical of the methods used due to their subjectivity which made her feel like she was not accurately representing herself.
Léopoldine	"How do you make sure someone fits their responses? How do you know their responses are trustworthy?" "There's subjective questions in there and the scores would depend on who does it."	**Somewhat unsatisfied** – She felt that the tool was lacking because it did not consider how to select the appropriate person to use the tool. Léopoldine also did not trust that other users' responses would to be trustworthy, however she did also indicate that she would find their results useful to better understand collaborators.
Magnon	"I thought it was unnecessarily complex. It wasn't hard tool to use it was just the way things were laid out was bizarre." "I get aggravated when things are more confusing than it needs to be."	**Mostly unsatisfied –** Magnon took particular issue with the language used within the tool. She felt that the vocabulary makes the tool unnecessarily take more time and that the process would be much simpler without it.
Simplice	"It was easy at first but there were sometimes when I was confused."	**Satisfied –** She was not voice many opinions specific to satisfaction, however she seemed generally satisfied with the result though acknowledged that some parts were confusing and that the example within the ranking could be clearer.
Toussaint	"Don't necessarily know what 'thematic' means"	**Satisfied –** Toussaint also did not voice many opinions during the study, however with the exception of not knowing what "thematics" meant immediately she seemed generally satisfied.
Zéphine*	"Maybe if you revise it, it could be easier to use."	**Mostly unsatisfied –** Zéphine liked many of the features of the tool and found it useful, however she felt that edits were needed to reduce the time required for the ranking process.

Table 8-6. Learnability based on concise-tool participants

	Characteristic Quote	*Summary of Characterization*
Azelma	"It's a little confusing but then when you go back and go back it's much more clear." "The context was pretty easy. The ranking, a little difficult but okay. [...] The most difficult was trying to understand the evaluation or the results I think."	**Mostly learnable –** Azelma asked questions but was able to answer them herself soon after. She was also able to correct herself if she made a mistake. However the tool did not provide her enough information to interpret the meanings dimensions.
Baptistine*	"I think the instructions weren't clear enough" "The image wasn't clear enough" "Am I doing this wrong? I'm obviously doing this wrong." "I don't know how to do this. I give up."	**Not learnable –** Baptistine struggled to use the instructions to correct herself when she made errors. Her expectations of what she thought the tool should work got in the way of her being able to effectively use the instructions. She ultimately was not able to figure out the ranking process without intervention.
Cosette	"You get the hang of it, at least what you think you're supposed to do."	**Somewhat learnable –** Cosette was generally able to use the instructions to figure out most processes, however was never confident that was actually doing it right.
Dahlia	"It was pretty self-explanatory."	**Learnable –** Dahlia indicated that she found it self-explanatory and was able to troubleshoot any questions she had successfully using the instructions and error messages.
Esmeralda*	"Who monitors these people? Are they supposed to just figure it out on their own?"	**Not learnable –** Esmeralda misinterpreted the instructions due to the word "rank" which she interpreted as "rate." She was not able to troubleshoot her errors using the instructions or buttons and ultimately chose to quit the study.
Fantine	"How to use the tool wasn't difficult necessarily, after the first couple rounds of ranking and all that, it made more sense towards the end."	**Learnable –** Fantine was able to fix her errors as she made them during the study.

Table 8-7. Learnability based on non-concise tool participants

	Characteristic Quote	*Summary of Characterization*
Juliette	"Pretty easy to figure out what I was supposed to do. I'm not entirely sure I did that second page right, the ranking of the different importances."	**Learnable –** Juliette was able to figure out how to use the tool fairly easily and correct herself as she made errors. However she was never confident that her work was correct.
Léopoldine	"So initially it's going to be difficult but it's easy in the end."	**Mostly learnable –** She struggled at first but was able to figure out at least how to avoid errors, even if she had not gone about it completely correctly.
Magnon	"I thought it was pretty complex." "I still don't fully understand what I'm looking at to be honest. I don't really understand the purpose or what it's supposed to show somebody."	**Mostly learnable –** Magnon was able to figure out the process though struggled to interpret the results in a meaningful way.
Simplice	"It wasn't that difficult if you know what your research or project is and the people you're working with, it's easy to put in everything."	**Learnable –** She was able to get a high level of understanding simply by following the instructions never receiving any errors.
Toussaint	"But overall, I think if you just play around with it you can kind of figure it out."	**Learnable –** Using the instructions, Toussaint was able to pretty easily figure out the process and get results.
Zéphine*	"The ranking. The explanation and how you score the most important was not clear for me, maybe it was clear but I did not understand it."	**Somewhat unlearnable –** Zéphine had eventually been able to figure out her errors through trial and error, however she struggled to effectively use the error messages and instructions.

Table 8-8. Usefulness based on concise tool participants

	Characteristic Quote	*Summary of Characterization*
Azelma	"There's a possibility someone might be surprised saying 'Oh, I did not think about this at all' or 'I missed this completely.' So I think it has the potential to be very useful."	**Somewhat useful –** Though she may not have felt that it was always useful, Azelma does feel that in some contexts it has a high potential.
Baptistine*	"I think it's very useful. I think the results, if you actually get results, could be very useful." "I wouldn't recommend it until the ranking section is clear."	**Somewhat useful –** Though she felt the tool could be useful if improved, as is she felt that it was too impossible to understand the tool to get any benefit from it.
Cosette	"At first I was a little skeptical, but looking at these charts and the results it does seem fairly useful."	**Somewhat useful –** Though she claimed she felt that it was fairly useful, she later suggest that it was less useful to her research context.
Dahlia	"I suppose in this organizational case, it does identify on paper that this organization has difficulties with communication and collaboration and has the capacity and willingness to implement and roll out project changes, so it is useful in that regard."	**Useful –** Though critical of the effort needed to use the tool, she did find the final results useful. She felt that it could be used to determine the weaknesses of collaborators to plan accordingly.
Esmeralda*	"If you really want good collaboration, good innovation, with multiple companies you just need two people who are chosen by their own managers who are allowed to just talk it out."	**Not useful –** She was generally critical of its usefulness and struggled to identify the objective of using the tool.
Fantine	"But as it stands now, unless you really broke it down for me, it's not useful as far as understanding strengths and weaknesses."	**Not useful –** She felt it did not really identify strengths and weaknesses at all and the results were ultimately not useful.

Table 8-9. Usefulness based on non-concise tool participants

	Characteristic Quote	*Summary of Characterization*
Juliette	"If I were to use this in a more complicated context, in an actual business project management context, what might happen is I might use it as an excuse to do what I was going to do anyway and use it to justify telling collaborators to learn about how fluid mechanics works or how to better design power tools."	**Somewhat useful –** Though not useful to her simple situation, Juliette felt the tool could be useful for helping make more complex decisions. She also felt it could be useful in convincing collaborators to make improvement actions.
Léopoldine	"So I guess early on a new project, we want to make sure we're on the same page and if we're not we want to find which areas are going to be problematic"	**Somewhat useful -** She identified that it would a useful communication tool between collaborators, however she was not sure how to ensure their responses would be reliable.
Magnon	"I kind of think it would good to use near the beginning. Just to make sure everyone is on the same page as far as skills and objectives." "I would tell them just to go the ranking page and go from there."	**Somewhat useful –** Magnon felt that a lot of the introduction and detail was not very helpful. She also felt that as an individual it was not useful, but that it would be useful as a communication tool between collaborators.
Simplice	"I think it's pretty useful if someone is actually in this kind of a situation where they are collaborating with someone working on a project to understand what needs to be worked on or what are the strengths of the organizations"	**Useful –** She felt that it would be particularly useful for collaborative situations to better understand others.
Toussaint	"Well for my research is wasn't but… it was pretty useful. It's as useful as the person putting the time in I guess"	**Somewhat useful –** Toussaint felt that though it was not useful to her context, it could be useful in a larger business context.
Zéphine*	"I think that it is really useful" "Maybe they can use previous projects so they can know what areas they need to improve on and they can compare and see that maybe this is easier just by scoring the importance of practices and by evaluating their capacity and willingness they can easily figure out which areas they need to work on."	**Useful –** Zéphine felt that the results could be useful, particularly for comparing an actor's profile for current and past projects.

Noticeably almost all users given the concise tool indicated that they found the tool to be inefficient. All users indicated that they felt that the tool required a lot of time, however participants whom were given the non-concise tool were actually more likely to feel that it was justifiable based on the usefulness of the results. As expected, most users when asked directly about the usefulness of the tool tended to answer positively which was most likely influenced by response bias. In commenting on the usefulness, most users focused on what they felt were the underlying goals of the tool regardless of how well they were able to use the tool to reach these goals. For this reason, efficiency may capture a more honest view on the tool's usability for most users.

Two participants – Esmeralda and Fantine – who both were given the concise version of the tool did indicate that they found the tool to not be useful. Esmeralda had been critical of the usefulness of the tool from the start which may have negatively impacted how well she was able to learn or get any justifiable benefit out of the tool. It is important to note that she did decide to quit the study before the end due to time restraints. Fantine on the other hand had received scores ranging from 100 to 58 and felt that the areas which the tool identified as being immature were only immature because they were not important and therefore did not find these to be weaknesses at all. This was a perfectly correct assessment and actually shows a high level of understanding in how the tool is supposed to be interpreted, however once she identified this she struggled to focus on seeing past the unimportant parts. Ultimately, because she felt that the tool had misidentified her weaknesses she did not find the tool useful at all.

Most users who had completed all parts of the tool when asked about the difficulty of figuring out the tool indicated that certain parts were more difficult that others but that they thought it was easy in the end. The ranking page was the most often identified as being the most difficult, however there were two notable deviations from this: Azelma and Magnon. Azelma identified interpreting the results as being the most difficult as she seemed to have more questions than answers. She had tried finding definitions for the dimensions to help in her interpretation but could not. Two participants from each tool had requested this same information when interpreting their results. How this information was presented was slightly different for the two version of the tool. Within the concise tool, only the dimension headers themselves are provided as shown in Figure 8-1, whereas in the non-concise tool a brief explanation is given as shown in Figure 8-2. When developing the concise version of the tool, it was believed that the descriptions originally provided became redundant which is why they were made more concise. Ultimately both figures, combined with the information included in the rest of the introduction should provide the same detail – or lack thereof – of the same information but at different levels of conciseness. This is in agreement with the findings of all four participants seeking more information on how to interpret the meaning of each dimension as none of them felt that the figures provided what they considered to be a definition.

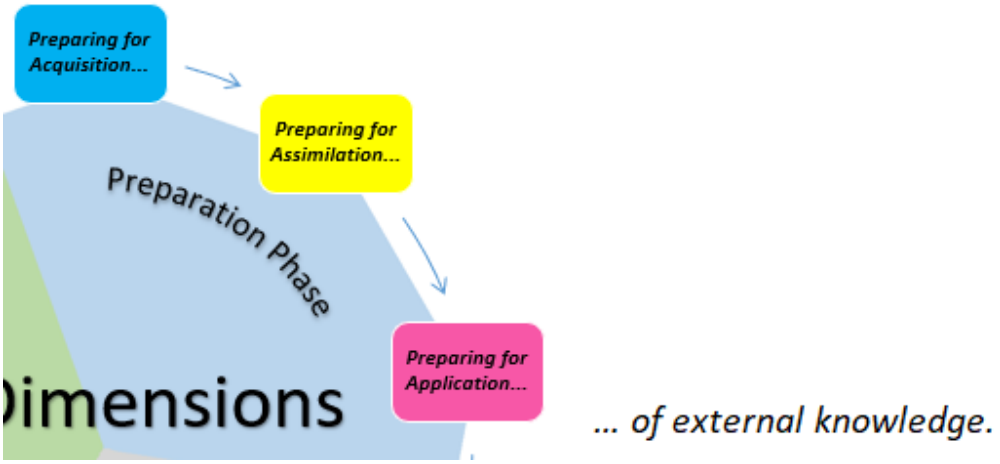


Figure 8-1. Concise tool description of dimensions within preparation phase

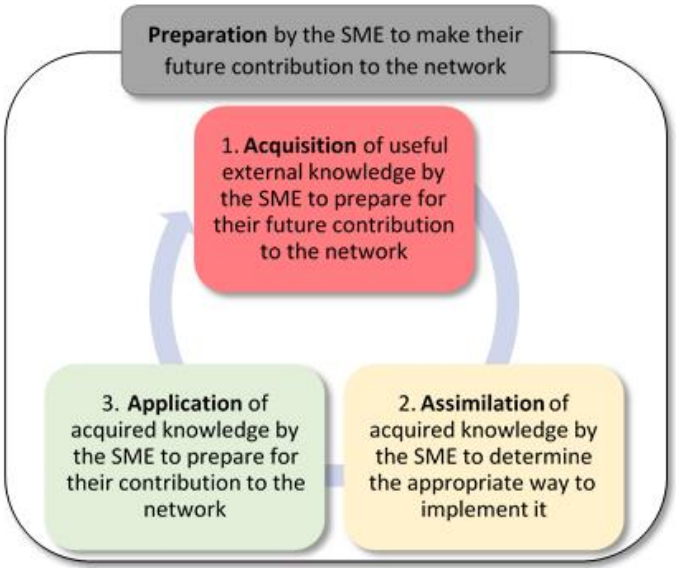


Figure 8-2. Non-concise tool descriptions of dimensions within preparation phase

Magnon had not tried to find these definitions, however she felt very strongly that the introduction was entirely unhelpful and had identified understanding it as the most difficult part of using the tool. She found it so unnecessarily complicated that she thought that organizations considering using the tool would be better off not having the introduction provided to them at all. Despite being a native English speaker, Magnon had been

incredibly unsatisfied with the complexity of the language used in the tool, particularly within the introduction. This was a sentiment similarly felt by Baptistine – a non-native English speaker – who had also complained about the complexity of the language "blowing her mind."

Some other dissatisfactions with the language used were shown by other participants. Dahlia – a native speaker – frequently complained about the managerial language used and that it took her longer to understand it. Esmeralda – a non-native speaker – similarly found the language difficult because she was not the "managerial type." Juliette – a native speaker – also felt that the tool would be more usable in the hands of a manger rather than a researcher like herself.

Although the language had made the process more difficult than they felt it should have been, the language complexity or managerial style had not prevented any of the native-English speakers from learning how to complete the tasks. Ultimately three users had not been able to complete the ranking process in the allotted time – Baptistine, Esmeralda, and Zéphine – none of whom are native-English speakers. Baptistine and Esmeralda has received the concise tool while Zéphine had been given the non-concise version. Baptistine was forced to give up after not being able to troubleshoot her misunderstanding using the instructions or error messages effectively. However, she had managed to complete one dimension successfully on her own prior to quitting. During Esmeralda's study, she chose not to use the red buttons to check her work despite knowing that they were there and as a result completed all dimensions incorrectly following her own logic rather than the instructions. Zéphine had eventually been able to figure out every step of the process,

however it had taken her 60% more time than the average for that task and I had to ask her to stop to ensure we would reach the debriefing interview in the allotted two hour period.

The misunderstanding that all three participants experienced seemed have could be traced back to the verb "to rank" which all three participants interpreted as "to rate." To better understand this and verify its definition, multiple dictionaries were review for each verb and are included in Table 8-10.

Table 8-10. Relevant dictionary definitions of "to rank" and "to rate"

To rank	**To rate**	Source
To determine the relative position of something	To set an estimate on something To determine or assign the relative rank or class of something	Merriam-Webster4
To make a list of things in order, comparing their importance, level of success, quality, etc.	To judge the value or worth of something	Cambridge Dictionary5
To give something a rank or place within a grading system	Assign a standard or value to something according to a particular scale	Oxford Living Dictionaries 6
To assign to a particular position, station, class, etc.	To estimate the value or worth of something To place in a certain rank, class, etc.	Dictionary.com7

As can be seen, according to all four dictionaries considered the verb "to rank" is specific to giving something a position within a list relative to other items. "To rate" can

[4] https://www.merriam-webster.com/dictionary/

[5] https://dictionary.cambridge.org/us/dictionary/english/

[6] https://en.oxforddictionaries.com/

[7] https://www.dictionary.com/

sometimes mean “to rank” rather than “to assign a value to” within certain contexts, however “to rank” always refers to positioning something within a list.

This common misunderstanding between these participants is believed to be analogous to my own experience as a non-native French speaker interpreting the meaning of the French version of instructions. Without a dictionary or other translation tool, my initial translation of the French instructions would look something like my translation first attempt and later interpretation as shown in Table 8-11. Important words are color coded to help follow my translation.

Table 8-11. Example direct translation as a non-native speaker

Original French	Classement des pratiques pour chacune des 9 thématiques d'absorption Pour chacune des neuf thématiques, il vous est demandé de positionner ses pratiques associées sur une échelle décroissante de niveaux, où le Niveau 1 correspond au niveau le plus important, le Niveau 2 signifie le deuxième niveau le plus important et ainsi de suite. Vous avez le droit de positionner plus d’une pratique sur un même niveau si leurs importances vous semblent égales. Le nombre de niveaux n’est pas fixé a priori. Toutefois le nombre maximum de niveaux est égal au nombre de pratiques à positionner; ce qui correspond à la situation où chaque niveau inclut exactement une seule pratique. Le nombre minimum de niveaux est, quant à lui égal à 1; ce qui correspond à positionner toutes les pratiques sur un même niveau. Ainsi les niveaux doivent être consécutifs ou bien ex æquo.
First attempt at English translation	Classification of practices for each of 9 thematics of absorption For each of 9 thematics, you are asked to position associated practices on a descending scale of levels, where level 1 corresponds to the most important level, level 2 means the second most important level and so on. You have the right to position more than one practice on the same level if their importances seem the same. The number of practices is not fixed at priority. Regardless the maximum number of levels is equal to the number of practices being positioned; that which corresponds to the situation where each level includes exactly one lone practice. The minimum number of levels is, XX to them equal to 1, that which corresponds to all positions the practices on the same level. Thus the levels must be consecutive or otherwise XX.
English translation after	Classification of practices for each of 9 thematics of absorption For each of 9 thematics, you are asked to position the related practices on a descending scale of levels, where level 1 corresponds to the most important

interpretations added	level, level 2 means the second most important level and so on. You are allowed to position more than one practice on the same level if their importances seem the same. The number of practices is not fixed. Regardless the maximum number of levels is equal to the number of practices being positioned; including the situation where each level includes exactly one lone practice. The minimum number of levels in all cases is equal to 1, which corresponds to when all the practices are positioned on the same level. Thus the levels must be consecutive.
Final English translation as it appeared in the non-concise tool	Ranking practices based on importance for each of the 9 ACAP thematics For each of the 9 thematics, the tool asks you to rank the practices based on their importance always starting with rank 1 being the most important practice. If the importance of some practices cannot be distinguished they are allowed to share rank. Ranks must be assigned consecutively however the number of ranks is not fixed. There may be some situations where there is only one practice within a certain thematic; in this case this practice must be assigned a rank of 1.

As can be seen, I was able to interpret the general meaning fairly accurately. Certain words like “ex aqueo,” which actually means “same rank”, I was not able to understand at all without a dictionary. However, since the same information was written in multiple different ways I was still able to overcome my confusion and understand what I needed to. Similarly, my original translation of “Classement des pratiques” as “classification of practices” seems unclear, however “Ranking of practices” is noticeably more specific.

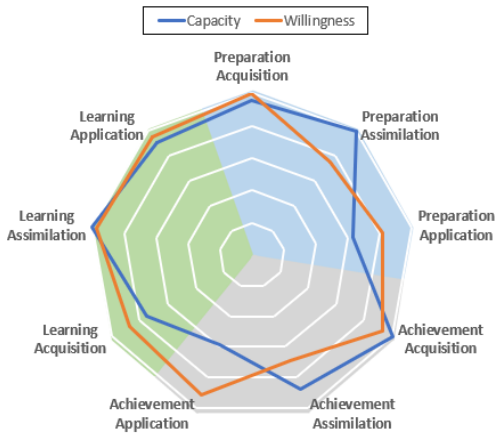
It is assumed that something similar may have happened for participants Baptistine, Esmeralda, and Zéphine. The verb was misinterpreted by all three participants, however only Zéphine – who had been provided the non-concise tool which had the instructions presented in multiple different ways – was eventually able to use correct her understanding. Baptistine and Esmeralda – who were given the concise tool which had had redundant information removed – could not.

8.3 Effectiveness

The following section will consider the effectiveness of the tool based off of what items participants were able to identify within their results interpretations, the time needed to complete tasks, and the errors which were made.

8.3.1 Results Interpretation Interview

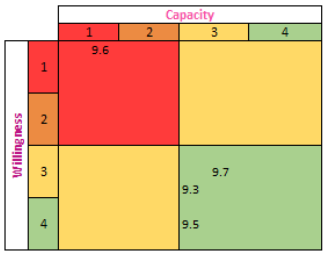
At the end of each study, participants were asked to interpret their results in a structured way. First, users are prompted to read the instructions and analyze the top section of the results. An example from one of the participants is included Figure 8-3. As can be seen, the scores are represented both graphically in the radar chart on the left and numerically in the table on the right. In addition to their scores, the relevancy to context of dimensions is also given. The results profile changes drastically between participants and the range varies between participants based on how critical they are of themselves. It is up to the user's interpretations whether the low scoring dimensions should actually be addressed. The relevancy of the dimension should help with this.



Copy Data	Maturity Scores		Relevance to Context
	Capacity	Willingness	
Preparation Acquisition	96	100	30%
Preparation Assimilation	100	75	20%
Preparation Application	63	82	57%
Achievement Acquisition	100	93	50%
Achievement Assimilation	88	69	43%
Achievement Application	58	92	20%
Learning Acquisition	75	88	64%
Learning Assimilation	100	98	100%
Learning Application	91	95	50%

Figure 8-3. Example radar chart and maturity scores table

Next participants are asked to interpret the lower half of their results which shows maturity grids for each dimension and the practices within it in a table ordered by their importance as shown in Figure 8-4. The maturity grids can be used to help identify immature practices which can then be considered in terms of how important they are shown on the right. In the example below, practice 9.6 is shown in the red meaning it was evaluated as being immature, however the importance relative to other practices is only 9%. Based on this the participant should identify that although it is weak, it is probably not worth focusing on.



No.	Importance	Practice
9.5	36%	Uses your organization's experience in the project to improve your organization's work skills
9.7	36%	Encourages individual creativity so that your organization fully realizes the benefit of the acquired knowledge from the project
9.3	18%	Finds new applications for your organization's experience from the project
9.6	9%	Establishes the means for promoting the application of new knowledge (change management, training, investments, etc.)

Figure 8-4. Example maturity grid and practices ordered based on importance for one of the nine dimensions of ACAP

To consider how effectively participants were able to use the results from the tool, a simple checklist was created. It is important to note that not all users were able to produce meaningful results which did tend to affect their ability to effectively interpret their results. The questions that were asked for each section are included in Table 8-12. Only the responses which occurred during that respective section of questions was counted towards that section. The evidence of these checklist items in highlight in yellow within the participant details included in Appendix D. The summary of the findings from the effectivity checklist are included in Table 8-13.

Table 8-12. Effectiveness of results interpretation checklist questions

Section	*Question*	*Example*
Top Half of Results	Was the user able to identify maturity of a specific dimension?	"We're strong in learning assimilation"
	Was the user able to identify maturity of a phase?	"So it looks to me that my organization has a good sense for learning."
	Was the user able to identify an overall maturity trend?	"My capacity and willingness seem to go together pretty well."
	Did they discuss their results in terms of their project?	"So I think it means that for our project specifically we like to use that knowledge that we gain from external sources to improve ourselves and learn from it."
	Did they use relevancy in their interpretation?	"Oh but the relevancy is only 40% so who cares."
Bottom Half of Results	Did they identify at least one practice strength/weakness?	"So I guess if I was using this as a management tool I would see 1.2, so I would say we're really good at exploring supply chain knowledge, we're good at staying informed using other organizations, and we are good with using experts." "And the yellow is okay, but the red is bad. […] Oh no. 3.14 is in the red."
	Did they identify at least one dimension strength/weakness?	"I could say learning assimilation seems to be an area of strength" "The preparation acquisition because the maturity scores are low."
	Did they identify at least one phase strength/weakness?	"I would take it as we know how to and we're willing to prepare for our project."
	Did they identify a generalized strength/weakness?	"I'd say an area of strength we have is our communication" "[Our weakness is] probably going external to our team."
	Did they identify the cause of at least one strength/weakness?	"I'd say our openness to new information of everyone on the team on the project" "Not necessarily needing to use external resources. We can find what we need internally. But I'm sure we could improve by going externally."
	Did they consider importance values within their interpretation?	"But it's only 4% important though so whatever."

Table 8-13. Summary of effectiveness of tool based on results interpretations

Top Section: Examine the radar chart and table next to it. Describe the meaning of these results relative to your project.					
	Identified specific dimension maturity	*Identified phase maturity*	*Identified overall maturity trend*	*Discussed project*	*Relevancy Interpreted*
Azelma	Yes	No	No	Yes	Yes
Baptistine	Yes	No	No	No	No
Cosette	Yes	No	Yes	Yes	No
Dahlia	Yes	No	Yes	No	Yes
Esmeralda	-	-	-	-	-
Fantine	Yes	No	No	No	No
Juliette	No	Yes	Yes	No	Yes
Léopoldine	No	Yes	No	No	Yes
Magnon	No	No	Yes	No	Yes
Simplice	No	No	Yes	Yes	No
Toussaint	Yes	No	No	No	Yes
Zéphine	Yes	No	No	No	No

Bottom Section: Analyze the other figures underneath for each dimension. Describe their general meaning. Please identify an area of strength. What do you think is the cause of this strength? Please identify an area of weakness. What do you think is the cause of this weakness?					
	Practice strength identified	*Dimension strength identified*	*Phase strength identified*	*Generalized strength identified*	*Cause of strength identified*
Azelma	No	Yes	No	Yes	Yes
Baptistine	No	Yes	No	No	Yes
Cosette	Yes	No	Yes	Yes	Yes
Dahlia	Yes	Yes	No	No	Yes
Esmeralda	-	-	-	-	-
Fantine	Yes	Yes	No	Yes	Yes
Juliette	Yes	No	No	Yes	Yes
Léopoldine	Yes	Yes	No	Yes	Yes
Magnon	No	Yes	No	Yes	Yes
Simplice	Yes	Yes	No	No	Yes
Toussaint	Yes	No	Yes	No	Yes
Zéphine	Yes	No	No	No	Yes

Table Continued…

Bottom Section: Analyze the other figures underneath for each dimension. Describe their general meaning. Please identify an area of strength. What do you think is the cause of this strength? Please identify an area of weakness. What do you think is the cause of this weakness?					
	Practice weakness identified	*Dimension weakness identified*	*Phase weakness identified*	*Generalized weakness identified*	*Cause of weakness identified*
Azelma	Yes	No	No	Yes	Yes
Baptistine	No	No	No	No	No
Cosette	No	No	No	Yes	Yes
Dahlia	Yes	Yes	No	Yes	Yes
Esmeralda	-	-	-	-	-
Fantine	Yes	No	No	No	Yes
Juliette	Yes	No	No	Yes	Yes
Léopoldine	Yes	No	No	Yes	No
Magnon	Yes	Yes	No	No	No
Simplice	No	Yes	No	No	Yes
Toussaint	Yes	No	No	Yes	Yes
Zéphine	Yes	Yes	No	Yes	Yes

	Importance Interpreted
Azelma	No
Baptistine	No
Cosette	No
Dahlia	No
Esmeralda	-
Fantine	Yes
Juliette	No
Léopoldine	Yes
Magnon	No
Simplice	Yes
Toussaint	Yes
Zéphine	Yes

As can be seen from the findings based on the interpretation of the top section, participants who were given the concise tool were more likely to identify specific dimensions within their interpretation. Most users regardless of which tool they were given failed to relate their results back to some aspect of their project specifically. There does not seem to be a clear trend between unmodified scenarios and their likelihood of discussing their project at this point in the study. Noticeably, twice as many participants who had been

given the non-concise tool had also chosen to interpret the relevancy of the dimension compared to those who had been given the concise tool. Though not definitive by any means, it does begin to suggest a slightly better level of understanding of the results by these participants who were given the non-concise tool. This trend appears again later when interpreting the bottom section of the results, as once again twice as many non-concise tool participants were able to identify specific practice weaknesses within their interpretations. Even more significant, four participants from the non-concise tool group chose to interpret importance when analyzing their results compared to only one person from the concise tool group.

8.3.2 Time Data

Time data will be used to consider the effectiveness of conciseness in reducing the amount of time needed to complete tasks. It is important to note that the prompt for the introduction task was changed slightly after the first four participants to include the NASA TLX workload assessment, however the time spent completing the workload assessment was not included in the times below. Table 8-14 and Table 8-15 give the timestamps of the start and end of each task according to the audio recordings which was used to calculated the elapsed time for that task. Each task started when I finished reading the prompt and ended when the participant indicated they were ready to proceed to the next task. Table 8-16 gives the average elapsed time values for each task. The adjusted values ignore those participants who were not able to complete the study, specifically Baptistine and Esmeralda who were given the concise tool and Zéphine who was given the non-concise tool. Figure 8-5 plots the elapsed times of participants give the concise tool as a bar chart with the average shown as a line. Figure 8-6 similarly shows the same information for the non-concise tool participants.

Table 8-14. Concise tool start and finish timestamps and elapsed time for task

		Review of Tool	*Introduction*	*Context*	*Ranking*	*Evaluation*
Azelma	*Start*	7m 47s	16m 34s	24m 32s	35m 37s	1hr 4m 47s
	Finish	14m 21s	24min 17s	35m 24s	1hr 4m 35s	1hr 14m 42s
	Elapsed	**6m 34s**	**7m 43s**	**10m 52s**	**28m 58s**	**9m 55s**
Baptistine	*Start*	3m 59s	7m 12s	13m 14s	21m 12s	
	Finish	4m 56s	12m 54s	21m 9s	41m 35s	
	Elapsed	**57s**	**5m 42s**	**7m 55s**	**Quit (20m 23s)**	
Cosette	*Start*	4m 25s	21m 22s	31m 22s	36m 47s	1hr 13m 25s
	Finish	19m 26s	23m 51s	36m 21s	1hr 12m 50s	1hr 24m 43s
	Elapsed	**15m 1s**	**2m 29s**	**4m 59s**	**36m 3s**	**11m 18s**
Dahlia	*Start*	5m 26s	16m 25s	27m 6s	31m 5s	56m 5s
	Finish	14m 5s	23m 36s	30m 50	55m 40s	1h 12m 31s
	Elapsed	**8m 39s**	**7m 11s**	**3m 44**	**24m 35s**	**16m 26s**
Esmeralda	*Start*	7m 24s	30m 11s	45m 27s	54m 19s	
	Finish	22m 4s	33m 51s	54m 5s	1h 25m 28s	
	Elapsed	**14m 40s**	**3m 40s**	**8m 38s**	**Quit (31m 9s)**	
Fantine	*Start*	3m 4s	6m 48s	13m 29s	18m 39s	51m 42s
	Finish	4m 15s	10m 2s	18m 21s	51m 42s	1h 10 m 43s
	Elapsed	**1m 11s**	**3m 14s**	**4m 52s**	**34m 3s**	**19m 1s**

Table 8-15. Non-concise tool start and finish timestamps and elapsed time for tasks

		Review of Tool	*Introduction*	*Context*	*Ranking*	*Evaluation*
Juliette	*Start*	1m 59s	11m 0s	14m 45s	20m 34s	42m 29s
	Finish	5m 38s	14m 32s	20m 17s	41m 34s	53m 9s
	Elapsed	**3m 39s**	**3m 32s**	**5m 32s**	**21m 0s**	**10m 40s**
Léopoldine	*Start*	3m 38s	16m 37s	20m 55s	24m 23s	46m 44s
	Finish	13m 38s	20m 40s	24m 11s	46m 8s	59m 47s
	Elapsed	**10m 0s**	**4m 3s**	**3m 16s**	**21m 45s**	**13m 3s**
Magnon	*Start*	2m 9s	8m 3s	28m 18s	33m 17s	56m 27s
	Finish	5m 32s	23m 12s	32m 59s	56m 12s	1h 5m 16s
	Elapsed	**3m 23s**	**15m 9s**	**4m 41s**	**22m 55s**	**8m 49s**
Simplice	*Start*	4m 59s	13m 48s	23m 29s	31m 3s	52m 16s
	Finish	9m 35s	18m 58s	30m 42s	52m 2s	59m 41s
	Elapsed	**4m 36s**	**5m 10s**	**7m 13s**	**20m 59s**	**7m 25s**
Toussaint	*Start*	4m 44s	10m 58s	19m 41s	26m 35s	1h 5m 19s
	Finish	7m 29s	16m 5s	26m 18s	1h 4m 39s	1h 21m 23s
	Elapsed	**2m 45s**	**5m 7s**	**6m 37s**	**38m 4s**	**16m 4s**
Zéphine	*Start*	3m 2s	6m 48s	18m 0s	23m 55s	1h 8m 55s
	Finish	4m 46s	14m 6s	23m 37s	1h 8m 12s	1h 20m 12s
	Elapsed	**1m 44s**	**7m 18s**	**5m 37s**	**44m 17s (Partial)**	**11m 17s (Partial)**

Table 8-16. Average and adjusted average time spent and standard deviations between participants in seconds for each task

		Review of Tool	*Introduction*	*Context*	*Ranking*	*Evaluation*
Concise Tool	*True Avg.*	**470**	**299**	**410**	**1751**	**850**
	Adjusted Avg.	471	309	366	1854	850
	True Std. Dev.	372	131	165	353	257
	Adjusted Std. Dev.	343	160	193	310	257
Non-Concise Tool	*True Avg.*	**261**	**403**	**329**	**1690**	**673**
	Adjusted Avg.	292	396	327	1496	672
	True Std. Dev.	176	260	84	617	185
	Adjusted Std. Dev.	176	290	94	443	207

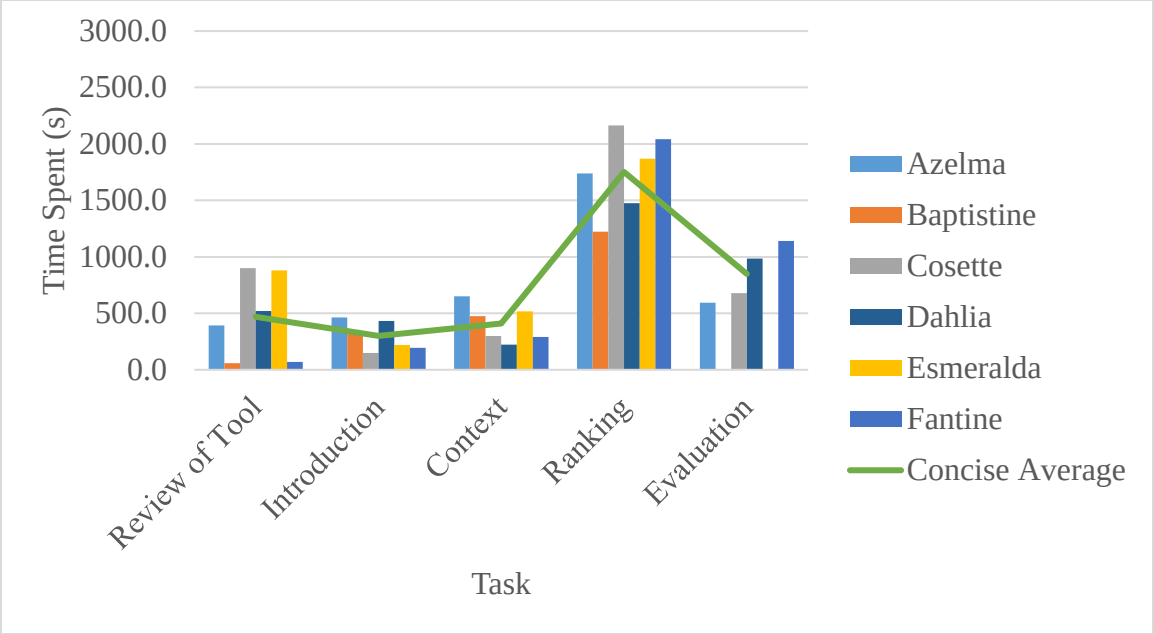


Figure 8-5. Concise tool elapsed time for tasks bar-chart

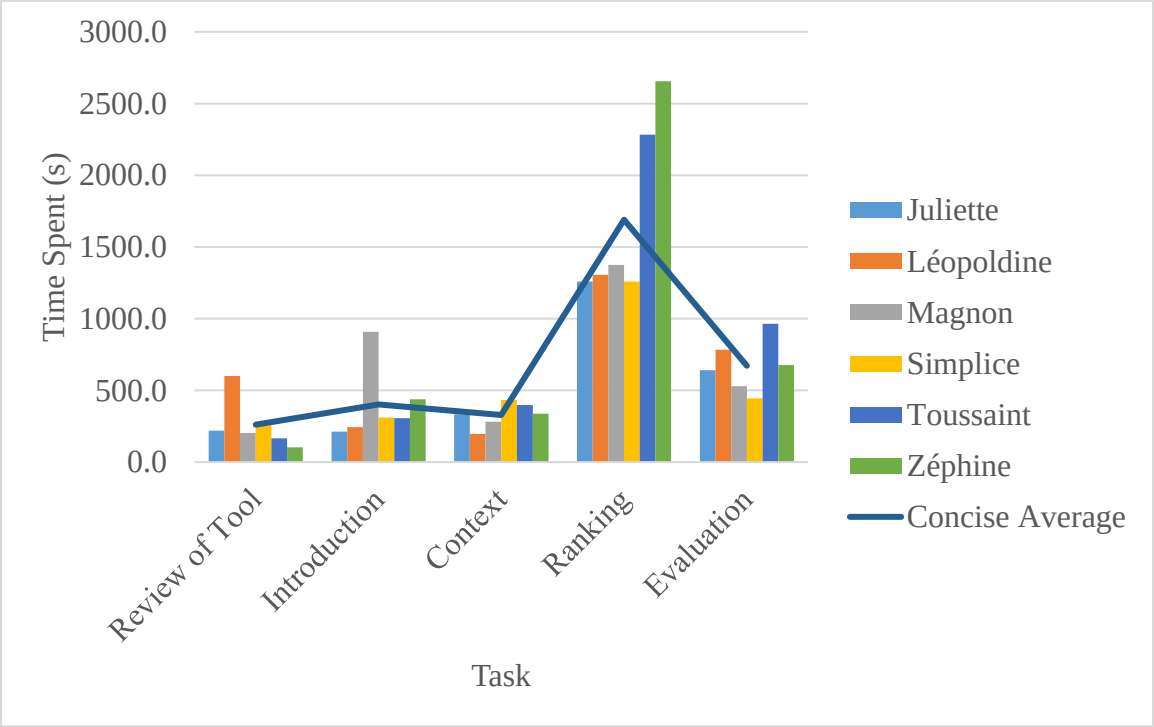


Figure 8-6. Non-concise tool elapsed time for tasks bar-chart

As can be seen from Table 8-16, the difference between the true average number of seconds needed to complete the ranking process for the concise and not concise tool is very close. The percent increase of the elapsed time needed to complete the ranking is only a 3.6% increase in the concise version of the tool with a difference from the non-concise version of only 61 seconds. However, the adjusted averages which ignore the times of participants who were not able to complete all parts of the study, shows a more significant difference. At an adjusted difference of 358 seconds, the percent increase is now a 23.9% increase in the time needed to complete the ranking using the concise tool.

It is important to note that the standard deviations between participants is relatively high for all tasks meaning that the average distance for the mean value for participants is high. Looking at Figure 8-5 which shows the elapsed times for each participant, there does not seem to be any trend of a particular individual consistently spending the most time or the least time on tasks. There also does not appear to be a relationship between time and their likelihood of finding the tool an efficient use of time. Azelma, who was the only participant who had been given the concise tool who had also found the tool to be at least somewhat efficient, actually had the median time spent for the ranking of the concise tool participants. Of the concise tool participants, Fantine was the only who completed the study and found the tool to be downright not useful. She did have one of the higher times but was still not the highest.

Now focusing on Figure 8-5 which shows the non-concise times, noticeably there appears to be two participants with extremely high times for the ranking process: Zéphine who had been asked to quit for the sake of time, and Toussaint. Excluding both of these

participants, the ranking process actually only took an average amount of time of only 1300 seconds with a standard deviation of only 54 seconds which is noticeably lower than the standard deviations for any other task despite those tasks consistently taking less time. The percent increase between this doubly adjusted average of 1300 seconds for the non-concise tool and the adjusted time from the concise at 1854 seconds is now up to a 43% increase with a difference of 554 seconds.

Ultimately, it would seem that the ranking process tended to actually take users longer when using the concise tool compared to when using the non-concise tool. This is believed to be because the average participant needs a longer period of time to understand less redundant, concisely written instructions compared to instructions written in a non-concise, more redundant way.

During the first four studies which included Azelma, Baptistine, Juliette, and Léopoldine, it was suspected that one of the reasons Baptistine had chosen to give up was not due to the time spent, but due to frustration and mental fatigue. Baptistine had actually spent less time on the ranking process compared to any other participant, however she had been noticeably the most verbally dissatisfied with earlier parts of the tool. It was believed that frustration and mental fatigue, which is specific to that participant, may have had a more noticeable effect on the learnability of the tool rather than the actual time needed. Esmeralda would later also not be able to complete the ranking process and had very similarly voiced a lot of dissatisfaction with the amount of time and effort required to use the tool prior to ever having reached the ranking process. To capture these effects, the

NASA TLX workload assessment was added to the study script and will be discussed in §8.4.

8.3.3 Errors

During each study, notes were taken by the facilitator which tracked the path of each user while completing the ranking task. Maps of these paths illustrating what dimension they were working on when they received certain errors or validation methods is included in Appendix D.

Table 8-17. Quantity of error and validation messages received

	Error Type										
	Step 1			*Step 2*			*Step 3*				
	C	*OM*	*CM*	*OM*	*Z*	*CM*	*O*	*<*	*CM*	*Total Errors*	*Valid*
Azelma	0	0	1	0	0	0	1	0	0	**2**	10
Baptistine	0	0	3	2	0	0	**0**	0	0	**5**	1
Cosette	0	0	1	0	0	0	**0**	0	0	**1**	11
Dahlia	0	0	0	1	0	0	**1**	0	0	**2**	11
Esmeralda	0	0	1	0	0	0	**0**	0	0	**1**	0
Fantine	0	0	0	1	0	0	**0**	0	0	**1**	9
Juliette	0	0	1	1	0	0	**0**	0	0	**2**	11
Léopoldine	0	0	0	0	0	0	**0**	0	0	**0**	9
Magnon	0	0	0	1	0	0	**0**	0	1	**2**	9
Simplice	0	0	0	0	0	0	**0**	0	0	**0**	9
Toussaint	0	0	1	1	0	0	**0**	0	1	**3**	10
Zéphine	6	0	10	2	0	0	**1**	0	0	**19**	11
Sum	**6**	**0**	**18**	**9**	**0**	**0**	**3**	**0**	**2**		
Adjusted Sum	**0**	**0**	**4**	**5**	**0**	**0**	**2**	**0**	**2**		

As can be seen from the table above, only two participants who had been given the non-concise tool had been able to complete the ranking with no errors at all. This suggests that the instructions alone, without verification from the error messages, may have been more effective in the non-concise tool compared to the concise version.

Noticeably, Zéphine who had been given the non-concise tool had considerably more errors than any other participant and actually accounted for 50% of the overall errors which occurred across all participants. Compared to the other two participants who had not been able to complete the ranking task in the allotted time, she was noticeably more willing to use the error messages to troubleshoot her errors. Baptistine and Esmeralda who had both been given the concise tool noticeably gave up using the error messages to help themselves very early on which was ultimately why they had to give up.

Ignoring these three participants, the adjusted quantity of each error type shows that the definition of a unit of difference in step 2 was responsible for the majority of errors. Noticeably, of the participants who were able to complete the task at all, only native speakers made this error. This particular step was expected to be the most familiar for all participants, so it is particularly curious that native speakers, regardless of which version of the tool they were given, were the most likely to make this error. This suggests that native speakers may have chosen to not read instructions as closely as their non-native speaker colleagues.

Also notable, is the fact that despite there only being nine dimensions, many participants decided to click the validation method an extra time for a dimension they had previously found correct. Considering the specific paths of users and their commentary at the time of revalidating, it is clear that many of these users decided to use the buttons to help troubleshoot their understanding to understand both what was correct but also what was considered wrong. Users were equally as likely to do this regardless of which tool they were given.

8.4 Workload

To further explore suspected factors which contribute to usability, the NASA TLX workload assessment was used. When completing this assessment, participants first indicate on a number line, generally from high to low, the point they feel matches their experience of workload. This number line represents a value v, between zero and one hundred for each workload source. Next, participants are asked to weight their number line values by comparing each workload source – a total of 15 comparisons - and identify the one that was the more important contributor. The quantity of times that a workload source is chosen as being more important is tallied and used as a multiplier w, which can range from 0 to 5. The workload amount and weight are then multiplied to produce a total workload based on that source. These workloads are then summed and normalized to be out of 100 points to produce an overall workload score W for that participant as shown in equation (8-1).

$$\frac{\sum_i^6 v_i w_i}{15} = W \tag{8-1}$$

The results of these calculations are included in Table 8-18 for concise participants and Table 8-19 for non-concise participants. Mental demand was hyphenated as MD, physical demand as PD, temporal demand as TD, performance as PF, effort as EF, and frustrations as FR. The differences between the initial and final assessment are included in Table 8-20.

Table 8-18. Concise workload

		Introduction							*Context, Ranking, Evaluation, & Results*						
		MD	*PD*	*TD*	*PF*	*EF*	*FR*	***W***	*MD*	*PD*	*TD*	*PF*	*ER*	*FR*	***W***
Cosette	*Rating*	65	10	45	85	40	70	**68.7**	85	25	25	30	65	40	**51.7**
	Talley	3	0	2	5	1	4		4	0	2	5	3	1	
	Total	195	0	90	425	40	280		340	0	50	150	195	40	
Dahlia	*Rating*	70	5	25	65	45	20	**44.7**	90	15	90	35	70	65	**74.7**
	Talley	4	0	1	2	3	5		5	0	4	1	3	1	
	Total	280	0	25	130	135	100		450	0	360	35	210	65	
Esmeralda	*Rating*	5	5	5	25	5	5	**7.0**							
	Talley	2	0	4	2	3	5								
	Total	10	0	20	38	15	23								
Fantine	*Rating*	65	15	50	80	65	20	**60.7**	90	55	85	55	70	50	**73.0**
	Talley	5	1	3	2	4	0		4	0	4	1	2	4	
	Total	325	15	150	160	260	0		360	0	340	55	140	200	

Table 8-19. Non-concise workload

		Introduction							*Context, Ranking, Evaluation, & Results*						
		MD	*PD*	*TD*	*PF*	*EF*	*FR*	***W***	*MD*	*PD*	*TD*	*PF*	*ER*	*FR*	***W***
Magnon	*Rating*	80	15	80	25	70	85	**75.3**	65	15	60	25	55	65	**53.7**
	Talley	5	0	3	1	3	3		5	0	2	3	4	1	
	Total	400	0	240	25	210	255		325	0	120	75	220	65	
Simplice	*Rating*	50	0	10	45	50	5	**40.0**	60	5	40	70	60	5	**57.0**
	Talley	4	0	2	5	3	1		4	0	2	5	3	1	
	Total	200	0	20	225	150	5		240	0	80	350	180	5	
Toussaint	*Rating*	45	5	15	65	35	30	**40.3**	75	5	60	65	60	75	**68.3**
	Talley	5	1	3	4	2	0		5	0	1	4	3	2	
	Total	225	5	45	260	70	0		375	0	60	260	180	150	
Zéphine	*Rating*	40	5	10	65	20	10	**37.7**	90	10	30	65	70	75	**73.7**
	Talley	5	0	2	4	3	1		4	0	1	2	3	5	
	Total	200	0	20	260	60	10		360	0	30	130	210	375	

Table 8-20. Changes in workload between the initial and final assessments

	MD	PD	TD	PF	EF	FR	W
Cosette	145	0	-40	-275	155	-240	**-17.0**
Dahlia	170	0	335	-95	75	-35	**30.0**
Fantine	35	-15	190	-105	-120	200	**12.3**
Magnon	-75	0	-120	50	10	-190	**-21.7**
Simplice	40	0	60	125	30	0	**17.0**
Toussaint	150	-5	15	0	110	150	**28.0**
Zéphine	160	0	10	-130	150	365	**37.0**

As can be seen in Table 8-20, most participants saw an increase in their overall workloads between their initial and final assessments. The two exceptions to this were Cosette and Magnon. During her initial review of the tool and her summary of the introduction, Manon verbalized a great deal of dissatisfaction with the language used. In fact she felt so strongly about this that she felt that she was better off not having had the introduction sheet at all. In Table 8-19, Magnon's frustration is a noticeably much weightier contributor to her experienced workload at a total of 255 for the introduction task but only 65 for the later four tasks.

Cosette is believed to have experienced higher workload during the introduction task due to the way the task had been presented to her which was slightly different than other participants because she had been the first to receive the NASA TLX assessment. Interestingly she was much more interested in her performance during the introduction task than she was for the later parts of the tool.

It would appear that the experience of workload is largely person dependent and less so on the tool they are given. However, the greatest change in experienced workload was Zéphine who had struggled the most with the ranking task compared to all other participants for both tools who had been given the TLX assessment.

Chapter 9. Recommendations

The following section will make generalized recommendations for improving the development of decision aid tools authored by academia. It is the hope that these recommendations can be used to give more researchers the satisfaction of having their decision aid tool research reach implementation.

Say it once and then say it again; redundancy may help non-native speakers.

Based both on the findings from the studies from Part 2 as well as from personal experience, having instructions presented in multiple ways was found to help non-native speakers figure out the meaning of keywords based on context clues. If these clues are eliminated simply to improve conciseness, it may cause these users to make errors due to misunderstanding that they may not be able to recover from or may take them an excessively long amount of time to do so. This is particularly important to keep in mind when writing instructions. It may be difficult to identify these troublesome keywords without extensive user testing which is often not feasible when developing a decision aid tool within academia. An easy way to remedy part of this problem is simply to present the instructions in redundant ways.

Conciseness may not always be such a time saver.

It was found during testing that the average user actually spent more time completing tasks using concise instructions than non-concise. Though it may be counterintuitive, presenting instructions in non-concise ways and thereby forcing users to spend more time thinking about these instructions may help users understand a new process quicker and complete the task faster.

Be careful about domain specific language; it can be helpful or hurtful.

Multiple users complained about the "complexity" and "managerial" terminology that was used within the tool. One user felt so strongly dissatisfied with the usage of this terminology, that she thought the tool was better off completely eliminating the introduction and all of its definitions. On the other hand, another user recognized some of the terminology that was used from their own past research which helped them better understand how the tool operated. Users seemed to prefer language that they recognize, regardless of if they had the ability to understand it or not.

Use neutral language; nobody likes to be told they are "weak."

A few users were noticeably defensive when told to identify areas in which they were weak. It is recommended that the language used – particularly when describing how to interpret the results of a self-evaluation – be as neutral as possible so that users are less resistant to change.

Seriously consider providing training.

An original requirement of the ACAP assessment was that the instructions "should be detailed enough that any user could learn the process with no facilitator present." However, it is now recommended to change this requirement to "should be detailed enough that any trained user will be reminded how to use the process without a facilitator present." The primary difference between instructions and training is the amount of effort required on the part of the user. The goal of training should be to reduce this workload and allow the user to focus their efforts on determining the usefulness of the tool instead.

A common dilemma within academia is that the expert developers of the decision aids often graduate before the tools ever reach the hands of an end user and as a result training

with an expert as a facilitator is often not possible. To remedy this, it is recommended to have developers create training videos or other training documentation that would only be needed the first time the tool is used by a new user. Doing so will hopefully help the end-user, but will also be an exercise for the developers in improving usability.

It needs to be functional, but it also has to look functional.

Though trustfulness was not a usability concern that had been recognized during Part 1 of this work, it was noticed during one of the studies from Part 2. One user indicated that they felt the tool "looked broken" and was noticeably less likely to trust other aspects of the sheet, particularly the buttons which she was worried would erase her data by accident. This seemed to have some effect how this user interacted with the tool as well as the likelihood of using its features.

Chapter 10. Conclusions

It was found that almost all of the predictions that were made were almost entirely wrong. The first of the research questions that was answered is included below:

RQ1: How does conciseness affect the usability of a decision aid tool in terms of its efficiency, effectiveness, satisfaction, learnability, and usefulness?

It was believed that conciseness would positively affect the usability, however this was found to not be case. The majority of users who had been given the concise tool found it to be inefficient whereas most users given the non-concise tool thought it was a reasonable use of time for the output they would get out of it. Similar levels of satisfaction were noticed between the two tools, though the non-concise tool did have ever so slightly more. The concise tool had had two participants who ultimately had to give up due to not being able to learn how to use the tool compared to the single non-concise user who had only been asked to stop for the sake of time. Most users regardless of the tool that they were provided thought that it would be useful, though the concise tool did win slightly in this category.

In terms of effectiveness, the non-concise tool tended to be the winner according to most metrics. Non-concise tool participants were more likely to interpret the relevancy and importance within their results which suggests a higher level of understanding in their results. Non-concise tool participants, despite having more instructions to read, actually spent on average less time completing the ranking process than users provided the concise set of instructions. It was also found that only two participants were able to correctly use the tool without triggering any errors, both of which had been given the non-concise tool.

RQ3: How does conciseness affect the usability of instructions specific to non-native speakers?

It had been predicted the conciseness would positively affect non-native speakers ability to learn instructions, however this was also found to not be the case. More concise instructions were found to rely upon the understanding of keywords more than non-concise instructions. Based on personal experience as well as the feedback from non-native speakers who were not able to complete all parts of the study, it is believed that redundancy within non-concise instructions may help non-native speakers troubleshoot their misunderstandings and improve learnability and effectiveness.

RQ4: How does conciseness affect the perceived workload of participants?

It was found that the perception of workload was largely participant specific. The majority of participants agreed that workload for the later tasks of the study was greater than the perceived workload for understanding and summarizing the introduction which was as expected. With the exception of one participant, it was also found that all participants for both tools agreed that there was an increase in mental demand for the later tasks, however the final amount of this demand was comparable across all users.

RQ2: What recommendations can be made to improve the usability of decision aid tools developed within academia?

Considering the findings from the research questions 1, 3, and 4, recommendations were developed with the goal of improving the usability of decision aid tools developed within academia. These recommendations were the following:

- Say it once and then say it again; redundancy may help non-native speakers.
- Conciseness may not always be such a time saver.
- Be careful about domain specific language; it can be helpful or hurtful.
- Use neutral language; nobody likes to be told they are “weak.”

- Seriously consider providing training.
- It needs be functional, but it also has to look functional.

Though the ACIC project is now over, an unofficial partnership between researchers at Clemson University, GINP, and the University of Rabat is living on. It is their future research to continue the development and testing of the collaborative innovation network tool which was developed during Part 1 of this work. An international industrial CIN case has been identified which can may be used for this purpose. The goals of this future research will be to adapt both the individual and network assessment tools to the identified case and then conduct a case study to validate the tools using the identified CIN. It is hoped that the usability recommendations included above will able to be taken into account within both tools moving forward.

Although the research from Part 2 accomplished the goal of exploring usability within a decision aid tool developed in academia that was later abandoned, the usability of a tool specific to the domain of engineering design has not. The context of these tools being demanded by industry and then being abandoned before implementation is comparable, and the recommendations that were developed in this work certainly apply to both, however further research is needed to understand domain specific usability concerns that may not have arisen while analyzing an innovation management decision aid.

AFTERWORD

As part of an industrial engineering Master's degree from a French university, two ACAP assessment tools were developed within Excel. To validate the individual actor ACAP assessment tool, eight usability studies were conducted which took approximately twelve hours to complete. All of these studies were conducted in French, five of which were fully transcribed and translated into English. These studies improved upon and validated the functionality of one of the tools, however the studies also identified some concerns about its usability in terms of its ease of use and simplicity. It was suspected that the lack of conciseness of the tool was complicating the process of understanding the tool making it less usable. Ultimately the poor usability of the tool caused its development to be revaluated.

From literature, it was found that usability was often forgotten by academia when developing engineering design enablers. Academic development of these kinds of tools usually focuses on the development of new knowledge and not directly concerned with how well that new knowledge is initially applied. It was suspected that, similar to the developed ACAP assessment tool, poor usability was causing these design enablers to also not reach full implementation which results in lessened research dissemination. Although it is not expected that academic developers will always be able to conduct usability studies themselves, consideration of usability is still appropriate.

With the goal of increasing research dissemination, it was decided to further investigate the usability of the ACAP tool which had been developed in order to make

recommendations to improve the likelihood of implementation for future tools. To do this, six think aloud studies were conducted on each of two English translations of the ACAP assessment tool. These twelve total studies alone took 24 hours to complete and generally took another six hours per study to create the full detailed summaries and interview transcriptions. Using these results, usability was characterized in terms of the tools' perceived efficiency, effectiveness, satisfaction, learnability, and usefulness. For the later eight studies, perceived workload was also assessed. Patterns were realized relating to conciseness, usability, workload, and language which were used to create a list of recommendations for improving usability of future decision aid tools.

Counter to what had been initially predicted, conciseness was found to have a generally negative effect on the tool's usability. Particularly for non-native speakers, redundancy within less concise instructions were found to improve both effectiveness and learnability. The experience of workload was found to be largely participant specific and not clearly related to conciseness. It was also found that domain specific vocabulary could be helpful or hurtful to user satisfaction. If the vocabulary used was familiar, participants seemed to better trust the tool. However, if the vocabulary was unfamiliar, the participant tended to be more critical of the tool. Negative vocabulary was also observed to make some participants less self-reflective. It is ultimately recommended to err on the side of overly redundant rather than perfectly concise instructions when developing decision aid tools. It is also recommended to phrase the language used in a way that users will be receptive to by avoiding negative or unfamiliar vocabulary.

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APPENDIX A: TRANSLATED LIST OF CRITERIA AND PRACTICES

English translated from its original French text. The French column is as it appears in the latest French version of the tool while the English is as it appears in all current versions of the English translation. These translations are in consideration of Benhayoun's earlier translations found in [8,97].

Context Criteria:

Environnement externe à la PME	**Dans votre secteur d'activité:**	*External environment to the SME*	**In your sector of activity…**
	Le niveau d'intensité technologique est élevé		The level of technological intensity is high (new science being used to enhance industry)
	La fréquence de l'innovation est élevée		The frequency of innovation is high
	Le niveau de concurrence est élevé		The level of concurrence/competition is high
Connaissances nécessaires pour contribuer au projet	**Pour contribuer à ce projet, vous aurez besoin de/ avez besoin de:**	*Knowledge necessary to contribute to the project*	**In order to contribute to this project, you need or will need…**
	Acquérir des connaissances à propos d'un composant ou d'une solution en dehors d'un usage particulier (Caractéristiques techniques …)		To acquire knowledge about a component or solution outside of a particular application (technical characteristics, etc.)
	Acquérir des connaissances sur la façon d'utiliser un composant ou une solution pour votre contribution au projet (Propriétés pour cet usage en particulier)		To learn how to use a component of solution specifically for your contribution to the project (specific to this application)

Rôle dans le projet	**Dans ce projet, votre organisation:**	*Role in the project*	**In this project, your organization…**
	Sera / est impliquée dans les interactions avec le marché ciblé par le projet		Is or will be involved in interactions with the target market of the project
	Sera/ est impliquée dans le management du projet		Is or will be involved in the management of the project
	Sera/ est impliquée dans la coordination technique du projet		Is or will be involved in the technical coordination of the project
	Aura/ a un droit de propriété intellectuelle plutôt exclusif sur l'innovation résultante (Plus le nombre de co-propriétaires augmente, plus l'exclusivité diminue)		Has or will have exclusive rights to the resultant intellectual property (As the number of co-owners of these rights increases, the exclusivity decreases)
Motivations pour le projet	**Vous prenez part à ce projet car ce dernier vous permettrait de:**	*Motivations for the project*	**You take part in the project because it allows you to…**
	Générer d'importants profits financiers		Generate significant financial profits
	Acquérir de nouvelles connaissances utiles à votre organisation en dehors de ce projet		Acquire new useful knowledge pour your organization outside of this project
	Initier un changement stratégique interne		Intitiate strategic internal changes

Positionnement par rapport aux partenaires du projet	**Parmi les partenaires du projet, certains ont:**	*Position relative to partners on the project*	**Certain partners on the project have…**
	Des bases de connaissances qui sont distantes des votres		Knowledge bases which are very different from your organization
	Des structures organisationnelles et/ou cultures industrielles distinctes des votres		Organizational structures and/or work cultures different from your organization
	Des activités et/ou compétences similaires aux votres		Areas of interest or competencies similar to your organization
	Des orientations commerciales similaires aux votres		Commercial orientation/direction similar to your organization

ACAP Practices:

	Préparation par la PME de sa contribution à venir au projet	**Preparation by the SME for its contribution to the project**
	Acquisition des connaissances externes à votre organisation, utiles pour préparer votre contribution à venir au projet	**Acquisition** of useful external knowledge to your organization to prepare for your future contribution to the project
1.1	Explorer des connaissances techniques et/ou technologiques liées à l'innovation envisagée (Théoriques, Usages, Acteurs compétents)	Explores techniques and/or technological knowledge related to the envisioned innovation (Theories, applications, qualified actors)
1.2	Explorer des connaissances en Supply Chain liées à l'innovation envisagée (Pratiques de la Supply chain, Acteurs compétents)	Explores Supply Chain knowledge related to the envisioned innovation (Supply chain practices, qualified actors)
1.3	Explorer des connaissances relatives au marché (Connaissances concernant les clients, compétition, tendances, opportunités, régulation, acteurs compétents)	Explores relevant market knowledge (Knowledge concerning clients, competition, market trends, opportunities, market regulations, qualified actors)
1.4	Explorer des connaissances en gestion de projet d'innovation (Financement, performance, planification et suivi d'un projet, acteurs compétents)	Explores innovation project management knowledge (Financing, performance, planning and follow-up on a project, qualified actors)
1.5	Explorer des connaissances en matière de collaboration interorganisationnelle (Connaissances juridiques, connaissances en coordination opérationnelle, acteurs compétents)	Explores inter-organizational collaboration knowledge (Legal, operational coordination, qualified actors)
1.6	Utiliser des sources de données adaptées (Bases de données scientifiques, Presse, Internet, Réseaux sociaux …) pour réaliser une veille des connaissances jugées utiles	Uses appropriate data sources (based on scientific data, press sources, internet search, social networks, etc) in order to stay up-to-date on knowledge judged to be useful
1.7	Vous renseigner auprès des organisations participantes, susceptibles d'apporter des connaissances utiles	Stays informed using other participating organizations likely to have useful knowledge
1.8	Vous renseigner auprès d'experts (Associations, clusters, consultants…) en dehors des organisations participantes	Stays informed using experts (Associations, clusters, consultants) outside of participating organizations
1.9	Participer à des évènements scientifiques ou industriels (Conférences, tables rondes…) pour vous procurer des connaissances utiles	Participates in scientific or industrial events (Conferences, discussion tables, etc) to procure useful knowledge

1.10	Explorer éventuellement tout domaine de connaissances utiles pour l'innovation envisagée	Explores any knowledge domain useful for the envisioned innovation
	Assimilation des connaissances acquises pour préparer votre contribution à venir au projet	**Assimilation** of knowledge acquired to prepare for your future contribution to the project
2.1	Impliquer activement le client le cas échéant	Actively involves the client as appropriate
2.2	Organiser des échanges avec les organisations participantes	Organizes occassions for communication between participating organizations (meetings, conversations, etc)
2.3	Utiliser des objets intermédiaires (Plans, Représentations, Documents supports, Simulation …) pour faciliter les échanges avec les organisations participantes et le client le cas échéant	Uses intermediary forms of communications (Plans, illustrations, supporting documents, simulations, etc) to facilitate communication between participating organizations and the client as appropriate
2.4	Réfléchir sur les risques et bénéfices de collaborer avec des entités qui peuvent vous être inhabituelles (Chercheurs, Grands groupes, Concurrents, Organisations que vous ne connaissiez pas avant etc.)	Considers the risks and benefits of collaborating with entities which are unusual to you (Researchers, large corporations, competitors, organizations you did not know before, etc)
2.5	Eventuellement collaborer en toute confiance avec des entités qui peuvent vous être inhabituelles (Chercheurs, Grands groupes, Concurrents, Organisations que vous ne connaissiez pas avant etc.)	Is open to the possibility of collaborating in full trust with entities which can be unusual to you (Researchers, large corporations, competitors, organization you did not know before, etc)
	Application des connaissances acquises pour préparer votre contribution à venir au projet	**Application** of acquired knowledge to prepare for your future contribution to the project
3.1	Définir et communiquer aux organisations participantes votre contribution au budget	Defines and communicates your organization's budget contribution to participating organizations
3.2	Définir et communiquer aux organisations participantes les spécificités de vos contributions opérationnelles à venir	Defines and communicates the specifics of your operational contributions to the future project to participating organizations
3.3	Désigner dans votre organisation les ressources humaines à allouer ou à dédier au projet	Designates the human resources from your organization to be allocated or dedicated to the project
3.4	Identifier les organisations participantes qui se trouveront à l'interface de votre contribution (que vous impactez et qui vous impactent)	Identifies the participating organizations which are connected to your organization's contribution (those that you impact and those which are impacted by you)

3.5	Définir les modalités de management du projet (Livrables et planning prévisionnel)	Defines the management methods of the project (Deliverables and provisional planning)
3.6	Définir les modalités d'évaluation de la performance de l'innovation envisagée (Objectifs attendus, critères d'évaluation et mode de pilotage)	Defines the performance evaluation methods of the envisioned innovation (Expectations, evaluation criteria, and management practices)
3.7	Mettre en place les outils collaboratifs nécessaires pour piloter les interfaces entre les différentes organisations participantes au projet (Bases de données partagées, Plateforme collaborative…)	Puts necessary collaborative tools in place to manage interactions between participating organizations on the project (Shared data bases, collaborative platforms, etc)
3.8	Définir et communiquer aux organisations participantes vos propres termes (Objectifs propres, règles habituelles de collaboration, particularités culturelles...) à prendre en considération	Defines and communicates your organization's personal terms (Personal objectives, usual rules of collaboration, cultural peculiarities, etc) for participating organizations to take into consideration
3.9	Définir un business model de l'innovation envisagée, approuvé par l'ensemble des organisations participantes concernées	Defines an envisioned innovation business model jointly approved by participating organizations
3.10	Désigner les acteurs d'interface nécessaires (Chef de projet, Coordinateur technique, Interface commerciale)	Designates necessary roles to participating organizations (project lead, technical coordinator, commercial representative)
3.11	Veiller à ce que les acteurs d'interface désignés soient approuvés (Légitimes et non conflictuels) par toutes les organisations participantes	Ensures that designated roles of participating organizations are approved (Legitimate and nonconflictual) by all participating organizations
3.12	Contractualiser les relations avec les autres acteurs qui sont jugées à risque	Contractualizes relationships with participating organizations who have been judged as risky
3.13	Evaluer la cohérence des objectifs du projet avec votre propre orientation stratégique (Risques et impact éventuel sur votre propre business)	Evaluates alignment project objectives with your organization's own strategic orientation (Risks and possible impacts on your own business)
3.14	Ajuster éventuellement vos propres objectifs en fonction de l'orientation commune du projet	Adjusts your organization's personal objectives as needed based on the common orientation of the project

	Réallisation par la PME de sa contribution effective au projet	**Achievement of their effective contribution to the project by the SME**
	Acquisition des connaissances externes à votre organisation, utiles pour réaliser effectivement votre contribution au projet	**Acquisition** of useful external knowledge to your organization to effectively make (or achieve) your contribution to the project
4.1	Vous informer à propos des contraintes et exigences des organisations participantes (Et du client le cas échéant) qui peuvent impacter la réalisation de votre contribution	Informs itself regarding the constraints and criteria of participating organizations (and of the client as appropriate) which can impact the achievement of your organization's contribution
4.2	Vous informer auprès des organisations participantes pouvant fournir des connaissances utiles à la réalisation de vos contributions	Informs itself using the knowledge of participating organizations useful to the achievement of your organization's contribution
4.3	Vous informer auprès d'experts externes au projet pouvant fournir des connaissances utiles à la réalisation de vos contributions	Informs itself using the knowledge of external experts useful to the achievement of your organization's contribution
4.4	Mobiliser des sources de données adaptées (Bases de données scientifiques, Presse, Internet, Réseaux sociaux...) pour vous procurer des connaissances utiles à la réalisation de vos contributions	Mobilizes appropriate data sources (Scientific databases, press, internet search, social networks, etc) to procure knowledge useful for the achievement of your organization's contribution
4.5	Participer à des évènements externes (Salons, formations, conférences...) pour vous procurer des connaissances utiles à la réalisation de vos contributions	Participates in external events (Exhibitions, trainings, conferences) to procure knowledge useful to the achievement of your organization's contribution
4.6	Explorer éventuellement tout domaine de connaissances pouvant être utile à la réalisation du projet	Explores any knowledge domain which is useful to the achievement of project objectives as needed

	Assimilation des connaissances acquises pour réaliser effectivement votre contribution au projet	**Assimilation** of acquired knowledge to effectively make your contribution to the project
5.1	Impliquer activement le client le cas échéant ou un utilisateur potentiel	Actively involves the client or potential end-user as needed
5.2	Organiser des échanges avec les organisations participantes se trouvant à l'interface de votre contribution (que vous impactez ou qui vous impactent) pour décider des usages en fonction de leurs contraintes et exigences	Organizes exchanges between participating organizations connected to your organization's contribution (those which you impact and those which impact you) to decide how they will be used based on their respective constraints and criteria
5.3	Organiser des échanges avec l'ensemble des organisations participantes au projet pour assurer la cohérence de la vision d'ensemble	Organizes group exchanges between participating organizations to ensure alignment of vision
5.4	Utiliser des objets intermédiaires (Création d'un langage commun, Prototypes, Démonstrateurs, Plans...) pour faciliter les échanges avec les organisations participantes et le client le cas échéant	Uses intermediary forms of communication (Creation of a common language, prototypes, demonstrations, illustrations, etc) to facilitate exchanges between participating organizations and the client as needed
5.5	Utiliser des moyens informatiques (Bases de données partagées, SharePoint ...) dédiés au partage des connaissances avec les organisations participantes et le client le cas échéant	Uses data processing methods (shared data bases, SharePoint, etc) dedicated to sharing knowledge with participating organizations and client as needed
5.6	Remettre en question les interventions et propositions des organisations participantes pouvant impacter la qualité de vos contributions	Challenges the interventions and propositions of participating organizations which can affect the quality of your organization's contribution
5.7	Intégrer éventuellement des connaissances et usages autres que vos propres connaissances ou façons de faire	Integrates the useful knowledge of others with your organization's own knowledge and practices as needed

	Application des connaissances acquises pour réaliser effectivement votre contribution au projet	**Application** of acquired knowledge to effectively make your contribution to the project
6.1	Travailler conjointement avec les organisations participantes se trouvant à l'interface de vos contributions	Works conjointly with participating organizations connected to your organization's contribution
6.2	Tester l'innovation générée avec le client le cas échéant ou un utilisateur potentiel avant sa commercialisation	Tests the generated innovation with the client or end-user as needed before commercialization
6.3	Promouvoir l'innovation générée dans des évènements pour faciliter sa mise sur le marché	Promotes the generated innovation during events meant to facilitate communication with the market
6.4	Utiliser des moyens techniques et/ou technologiques adaptés pour réaliser vos contributions au projet (Plateforme technologique, Site web, etc.)	Uses technical methods and technologies to make your organization's contribution to the project (Technology platform, web sites, etc.)
6.5	Elaborer un descriptif documentant vos contributions accomplies	Documents your organization's accomplished contributions
6.6	Remettre en question vos contributions pour atteindre les plus hauts niveaux de performance	Challenges your organizaiton's own contributions in order to attain the highest level of performance
6.7	Soulever rapidement vos doutes afin d'éviter les incompréhensions pouvant empêcher l'atteinte des objectifs du projet	Quickly raises any doubts in order to avoid misunderstandings which could prevent meeting the objectives of the project
6.8	Allouer éventuellement des ressources supplémentaires (Humaines, financières...) propres à votre organisation	Allocates additional resources as needed (Human, financial, etc) from your own organization
6.9	Apporter votre aide à toute organisation participante qui en a besoin	Provides assistance to any participating organization who needs it
6.10	Ajuster éventuellement votre contribution accomplie suite à la requête du client ou d'une autre organisation participante	Adjusts your organization's contribution following the request of a client or other participating organization as needed

	Apprentissage par la PME de son expérience dans le projet	**One-Way Learning by the SME based on their experience in the project**
	Acquisition de nouvelles connaissances dans le cadre de votre participation au projet, pouvant servir d'apprentissages à votre organisation	**Acquisition** of new knowledge during your participation in the project which can provide learning opportunities at your organization
7.1	Collecter des connaissances techniques et/ou technologiques (Théoriques, Usages, Acteurs compétents)	Collects technical knowledge and/or technologies (Theories, applications, qualified actors)
7.2	Collecter des connaissances à propos du marché (Connaissances concernant les clients, compétition, tendances, opportunités, régulation, acteurs compétents)	Collects market knowledge (Knowledge concerning clients, competition, market trends, opportunities, market regulation, qualified actors)
7.3	Collecter des connaissances en supply chain (Pratiques de la Supply chain, Acteurs compétents)	Collects supply chain knowledge (Supply chain practices, qualified actors)
7.4	Collecter des connaissances en gestion de projet d'innovation	Collects innovation project management knowledge
7.5	Collecter des connaissances en matière de collaboration inter-organisationnelle (Connaissances juridiques, connaissances en coordination opérationnelle, acteurs compétents)	Collects inter-organizational collaboration knowledge (Legal knowledge, coordination of operations, qualified actors)
7.6	Repérer lors de votre participation à des évènements en lien avec le projet (Salons, Conférences, Tables rondes...), des connaissances également utiles à votre organisation	Collects knowledge which is useful to your organization from external events (Exhibitions, conferences, discussion tables, etc.) during your participation in the project
7.7	Organiser une réunion de bilan à l'issue du projet pour collecter les retours d'expériences potentiellement utiles à votre organisation	Organizes a final review meeting at the end of the project to collect feedback potentially useful to your organization
7.8	Organiser des réunions de bilans intermédiaires pour collecter des connaissances potentiellement utiles à votre organisation	Organizes intermediary review meetings to collect knowledge potentially useful to your organization
7.9	Vous informer, si possible, formellement ou informellement auprès des organisations participantes pouvant fournir des connaissances utiles à votre organisation	Informs itself, if possible, formally or informally using participating organizations which could have useful knowledge to your organization
7.10	Mettre en place des apprentissages continus tout au long du projet (Rapports d'étonnements, bases de données …) pour conserver les connaissances potentiellement utiles	Establishes continuous learning steps throughout the project (Discovery report, data bases, etc) to conserve potentially useful knowledge

7.11	Vous intéresser à tout type de connaissances même au-delà de votre propre domaine d'expertise	Pursues any type of knowledge even if it is not in your own domain of expertise
	Assimilation des connaissances acquises dans le cadre de votre participation au projet, pouvant servir d'apprentissages pour votre organisation	**Assimilation** of knowledge acquired during your participation in the project which can provide learning opportunities at your organization
8.1	Organiser des échanges avec vos collaborateurs internes à propos des connaissances acquises du projet	Arranges communication between collaborators within your organization to share knowledge acquired during the project
8.2	Utiliser des objets intermédiaires (Plans, Représentations, Simulation …) pour faciliter les échanges avec vos collaborateurs internes à propos des connaissances acquises du projet	Uses intermediary forms of communication (Plans, illustrations, supporting documents, simulations, etc) to facilitate the sharing of knowledge acquired during the project between collaborators within your organization
8.3	Utiliser des moyens informatiques (Bases de données partagées, SharePoint, …) pour stocker et partager les connaissances jugées utiles pour votre organisation ou pour certains de vos collaborateurs internes	Uses data processing methods (Shared data bases, SharePoint, etc) to store and share knowledge judged useful to your organization or to certain collaborators within your organization
8.4	Communiquer les connaissances jugées utiles pour votre organisation ou pour certains de vos collaborateurs internes	Communicates knowledge judged useful to your organization or to certain collaborators within your organization
8.5	Echanger avec tout individu de votre organisation afin d'identifier des usages pertinents des connaissances acquises du projet	Communicates with all individuals of your organization in order to identify relevant uses of acquired knowledge from the project
	Application au sein de votre organisation des apprentissages issus du projet	**Application** of things learned during the project within your organization
9.1	Utiliser votre expérience dans ce projet pour améliorer la compétitivité de votre organisation	Uses your organization's experience from the project to improve the competitiveness of your organization
9.2	Utiliser votre expérience dans ce projet pour améliorer l'efficience de vos autres projets	Uses your organization's experience from the project to improve the efficiency of your other projects
9.3	Utiliser votre expérience dans ce projet pour créer de nouveaux usages	Finds new applications for your organization's experience from the project
9.4	Utiliser votre expérience dans ce projet pour améliorer les pratiques de certains métiers dans votre organisation	Uses your organization's experience from the project to improve the practices of certain areas within your organization
9.5	Utiliser votre expérience dans ce projet pour renouveler vos outils de travail	Uses your organization's experience in the project to improve your organization's work skills

9.6	Mettre en place tous les moyens nécessaires pour favoriser l'application des apprentissages (conduite au changement, formations, investissements …)	Establishes the means for promoting the application of new knowledge (change management, training, investments, etc.)
9.7	Encourager la créativité des individus pour permettre à l'organisation de tirer profit des connaissances acquises du projet	Encourages individual creativity so that your organization fully realizes the benefit of the acquired knowledge from the project
9.8	Anticiper l'usage possible des connaissances acquises du projet en les adaptant au contexte de votre organisation	Adapts the acquired knowledge from the project to the context of your organization in anticipation of possible applications

Actor Role Criteria:

Fait partie des principaux porteurs du projet	Is the primary leader of the project
Est impliqué de façon plutôt exclusive dans la propriété intellectuelle de l'innovation	Has the exclusive intellectual property rights of the innovation
Est fortement impliqué dans la prospection de nouveaux acteurs à inclure dans le réseau	Is heavily involved in the search for new actors to include in the network
Est fortement impliquée dans la promotion et/ou la commercialisation de l'innovation	Is heavily involved in the promotion and/or commercialization of the innovation
Est fortement impliqué dans la gestion du projet collaboratif	Is heavily involved in the management of the collaborative project
Est fortement impliqué dans la coordination technique du projet collaboratif	Is heavily involved in the technical coordination of the collaborative project

APPENDIX B: STUDY SCRIPTS

The following is the script that was used for all participants once the workload assessment was added to the protocol during Part 2.

Study Script

Facilitator: Elizabeth Gendreau
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Project PI: Dr. Joshua Summers
jsummer@clemson.edu

Introduction (~5 min)

Hello, my name is Elizabeth and I'm going to be walking you through this session today. The PI on this project is Dr. Joshua Summers. If you need to contact either of us our contact information is at the top of this sheet.

You may already known why we're here, but I'm going to go over it again briefly. We are trying to test a recently developed survey tool to learn more about how it is used. The session is expected to take around an hour and a half.

During the study, I am going to ask that you try to think aloud as much as possible and to tell me what you're looking at, what you're trying to do, or what you may be thinking. Ultimately, I'm going to ask you to narrate your thought process while using the tool. Keep in mind that we are testing the tool and not you, so don't worry about making mistakes. Nothing you do here is wrong.

I will now give you some additional information about being in a research study at Clemson University. By participating in this study, you are giving us permission to record your responses and the audio from today's session which will be used for research purposes. Please take what time you need to review this document and let me know if you have any questions. As this form explains, you are under no obligation to participate in this study and may stop at any point. All identifying information will remain confidential.

Initial Questions (~5 min)

Before inspecting the tool, I would like to ask you some basic questions.

- What research projects are you currently working on? Describe them briefly.
    - At what phase in the project are you?
    - When did this project start? What is the expected completion date?
- Are you familiar with the concept of Absorptive Capacity?
- What about the notion of a Collaborative Innovation Network?
- Have you ever used Simos' method?

Initial Review of Tool (~5 min)

At this stage I am going to ask you to look at each sheet and tell me what stands out, if there is any content which seems bizarre or what initial opinions on it you might have. It is not necessary to read everything at this stage. You may scroll and navigate between sheets, but do not click on anything for the moment.

Scenario (~10 min)

For the rest of the study you represent an SME (Small to Medium Sized Enterprise) within a CIN (Collaborative Innovation Network) and you are working together on an innovation project. In this scenario, imagine that one of your research projects is the project being worked on. Everyone at Clemson on your research team including your advisor(s) are a part of your SME that you are representing. Any other industry partners which are involved in your project would be considered other members of your Collaborative Innovation Network.

You may not be familiar with the idea of Absorptive Capacity, but you wish to learn about it, so it can be used to your advantage. You have received the tool in front of you to do this.

We realize that your research team at Clemson is not really an SME, so you may have to use your imagination at certain points during the study. Remember that the objective of the study is to evaluate the tool and not you or your response accuracy.

Using the Tool (~1 hr 20)

Now I am going to ask you to do a series of tasks using the tool. If at any time you need me to clarify a task, don't hesitate to ask. Also, if you think that certain parts of the task are too complicated or difficult to understand, let us know. Don't be afraid to be critical. The more feedback you can give us, the better.

However, I may choose not to respond to certain questions or may ask you to refer back to the instructions. Alternatively, I may tell you not to worry about certain things as they may not be important to our study.

As previously stated, you are more than welcome to stop the study at any point. If you simply need a break, let me know and we can pause the test. Before we begin, do you have any questions?

Tasks

1. Navigate to the Introduction sheet. Please read for understanding. At the end I will ask you to provide a summary of what you have read. Let me know what feedback you may have and when you are ready to provide a summary.

NASA TLX Introduction Effort Evaluation

2. Navigate to the Context sheet. Read and follow the instructions at the top of the sheet. Don't forget to speak aloud. Indicate when you are finished.
3. Navigate to the Ranking sheet. Carefully read the instructions at the top and refer to them again as needed. Complete the steps for each dimension/thematic. Don't forget to speak aloud. As always, let me know where you are finished.
4. Navigate to the Evaluation sheet. Read the instructions at the top and complete the evaluation for each dimension. Let me know where you are finished.
5. Navigate to the Results sheet. Read the instructions and then examine the radar chart and the table next to it. Describe the meaning of these results relative to your project. Next, analyze the other figures underneath for each dimension. Describe their general meaning and explain how you would interpret these.
    a. Please identify an area of strength. Why do you think is the cause of this strength?
    b. Please identify an area of weakness. What do you think is the cause of this weakness?
    c. What action would you recommend that YOUR ORGANIZATION take to improve in an area(s) where it may be weak?
    d. What action would you recommend that YOU take to improve in an area(s) where you or your organization is weak?

NASA TLX End Effort Evaluation

Debrief (~10 min)

- Overall, how easy or difficult was it to figure out how to use the tool?
    - Which parts of the tool were the most difficult and why?
    - Which were the easiest and why?
- How do you perceive the amount of effort needed to use the tool?
- How do you perceive the overall usefulness of the tool?
- How do you perceive the amount of time needed to use the tool survey?
- If you used the tool for a future collaborative project, when during the project would you use it and how?
- What recommendations would you offer an organization considering using this tool?
    - What characteristics would an organization need to get the maximum benefit out of using this tool?
- What would you say are the most important things that you learned from using the tool today?

Conclusion (~5 min)

Do you have any further questions or input?

Thank you for your help!

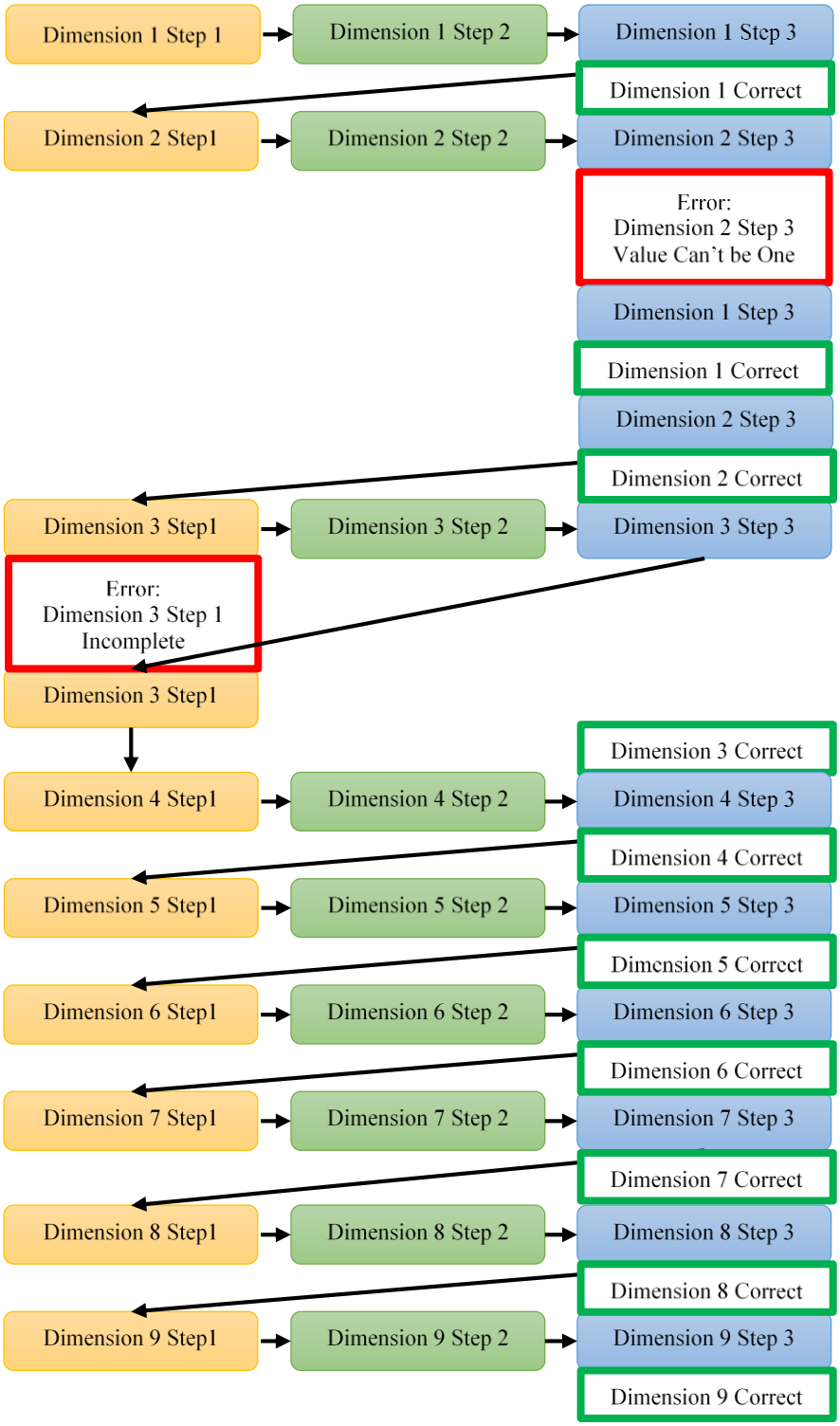
APPENDIX C: COMPARISON OF SRF IMPLEMENTATIONS

	Original SRF	*Direct SRF*	*Controlled Scale SRF*	*Uncontrolled Scale SRF*
Question Asked	If the smallest interval has a difference of one unit, ***how many more units*** are the other intervals?	If the smallest interval has a difference of one unit, ***how many units*** are on each interval?	Given a scale from the ***smallest interval to the largest***, rate the difference of each interval.	Given a scale from ***small to large***, rate the difference of each interval.
Definition of Unit	**OK** If done correctly, unit is defined relative to smallest interval	**OK** If done correctly, unit is defined relative to smallest interval	**OK** If done correctly, unit is defined relative to smallest interval	**OK** Unit defined relative to smallest defined interval
Ability to control understanding	**OK** Possible to programmatically force DM to indicate at least one interval as 0 *more* units, thus controllable	**OK** Possible to programmatically force DM to indicate at least one interval as 1 unit, thus controllable	**OK** Possible to programmatically force DM to indicate at least one interval as 1 unit, thus controllable	**Not OK** No control possible to ensure DM understands values are relative to each other, *to the DM the smallest interval is not necessarily equal to 1 unit - even if the scale can be mathematically adjusted so that it is*
Avoidance of over-constraining DM	**OK** DM has no limit as to the maximum difference on a particular interval	**OK** DM has no limit as to the maximum difference on a particular interval	**Not OK** DM is limited to using a scale which may over-constrain their response	**Not OK** DM is limited to using a scale which may over-constrain their response

APPENDIX D: PARTICIPANT DETAILS

The following subsections are broken up by participant in alphabetical order. Within each subsection is an error map, a detailed summary of the participant's usage of the tool as well as their responses during the initial interview, further development of their scenario, interpretation of their results, and debrief. Each participant's details can be found on the following pages:

Azelma


Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Dimension 1 Correct
Dimension 2 Step1
Dimension 2 Step 2
Dimension 2 Step 3
Error:
Dimension 2 Step 3
Value Can't be One
Dimension 1 Step 3
Dimension 1 Correct
Dimension 2 Step 3
Dimension 2 Correct
Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Error:
Dimension 3 Step 1
Incomplete
Dimension 3 Step1
Dimension 3 Correct
Dimension 4 Step1
Dimension 4 Step 2
Dimension 4 Step 3
Dimension 4 Correct
Dimension 5 Step1
Dimension 5 Step 2
Dimension 5 Step 3
Dimension 5 Correct
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Dimension 6 Correct
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Dimension 9 Correct

Azelma was a non-native English speaker and PhD student. She had some idea about the meaning of absorptive capacity and a fairly good understanding of the notion of a collaborative innovation network, however she had never used Simos' method.

The scenario that Azelma used was based on her PhD research project which involves creating a method for modeling a bicyclist's energy consumption. She discussed that the research had been around since as early as 2014 but that her part in the project had started January of 2016. She estimated that she was about 70% complete and expected to finish in December of 2018. She did note that a PhD student collaborator at Clemson would continue working on a different part of the same project into the Spring of 2019. Two Mechanical Engineering faculty were advisers on the project. A faculty member at a different university was also identified as an external collaborator. During the study Azelma identified this faculty member as being from the Health Sciences department.

Azelma was given the concise version of the tool. During her initial review of the tool, she did have to refer to the script to make sure she understood the acronym SME. She also noted the coloring scheme of some of the headers and that she expected them to be connected somehow.

During the introduction task, Azelma asked to verify whether the dimensions referred to the preparation, achievement, and learning phases but later went on to explain what she thought the three phases meant and identified that there were nine dimensions being evaluated. She was able to note that her responses to the context statements would be used to identify the practices within each of the nine dimensions which best align with the project at its current stage. She stated that she believed that she would be ranking the

dimensions which were somehow connected to the evaluation of capacity and willingness. Azelma was initially unsure if she was evaluating capacity and willing based on her organization's ACAP or on how well she used the tool but was able to find her answer using content from the introduction. Azelma also noted that the scores she would receive at the end would be used to identify strengths, weaknesses, and capabilities.

While completing the context, Azelma requested the definition of innovation but was denied. When she reached the "level of concurrence/competition" context statement she was unclear about the meaning and interpreted it as "somebody else is doing the same thing." She began to put 4 for this value but changed it to 3 due to her uncertainty. Upon reaching the "to acquire knowledge about a component or solution" context statement she briefly discussed the difference in expertise of her collaborators at Clemson versus those at the other university. She was again unsure how to respond to this statement and noted that she was lowering her score to account for this. At the "resultant intellectual property" context statement she noted that she was not sure Clemson's policy on intellectual property involving other universities. She considered that Clemson would most likely not have exclusive rights and therefore put 1. When considering the motivations for working on this project she considered one of the objectives of the project to be to make future proposals and get funding for future research though she was unsure if this counted as financial profits or not. Upon reaching the "knowledge bases which are very different from your organization" she noted that she originally interpreted it as "rival organizations" rather than partner organizations but corrected herself using content from the sheet.

When initial reviewing the instructions on the ranking sheet, Azelma came across "if there are no user-input cells, no action is required" and asked what this meant though she was denied. The first time that Azelma indicated that at least two practices shared the same rank occurred during the first dimension. During this first dimension she initially indicated that she did not understand the meaning of "smallest difference." She questioned whether it was asking for the difference between ranks 1 and 2 or something else. She put 1 for the first of the pairs and then stated "this is easy, it's a little confusing but then when you go back and go back it's much more clear." She then quickly concluded that between 2 & 3 should also be 1 unit and completed the final step. She clicked the help button for this first dimension and found that **she was correct** before starting on the next dimension.

Only 2 practices appeared for the second dimension. She initially put 1 for step 3, so when Azelma clicked the help button for the first time for this dimension **she was notified that her response for step three could not be less than or equal to one.** She noted that her confusion was due to there only being two ranks. After rereading the header she was able to conclude that the highest rank was actually 2 times more important.

She then went back to the first dimension to make sure she had done it correctly. She considered changing her response to 1/3 as the lowest rank was 3 and the highest rank was 1. At this point she decided to review the instructions and concluded that she needed to divide the ranks and concluded that her response should be 3. She then **validated her work** using the button.

She then returned to step 2 and verbally confirmed that she thought her response to step 3 should be 2 on the grounds that the lowest rank was 2. **She validated** this using the button.

She then moved on to dimension 3 where 9 practices were shown. Upon reading these she commented that "Oh man, this is long." She gave five of these practices a rank of 1 while the other four were given a rank of 2. Azelma asked whether the practices were supposed to be relevant to her project or if they were just generic for any project. She concluded that they should indeed be relevant to her project but noted that her organization had not actually done all of the practices listed. She specifically mentions that her organization never came up with any legal documents which was most likely in reference to practice 3.11 or 3.12 which pertain to approval of roles within the project and contractualizing relationships respectively. She also noted that her organization did not deem anyone to be risky because there was only one partner organization on her project and that there was not much money being contributed to the project to begin with. "Nothing was official," Azelma stated. "When we met with the partners on regular weekly meetings or biweekly meetings, that's when we discussed all these things and it's a little hard for me to rank this based on the preparation phase of the project I'm working on right now but if I were to do it on a new project – which would probably be different from what I'm doing right now – if it requires that it be done I would do these. Having said that, if something is irrelevant to the project how do I score it? Give it a low rank?" She further noted that she did not believe she could leave these cells that she found irrelevant empty. After attempting to ask if this was the case and being denied she opted to use the **help button to**

troubleshoot her question. After deleting one of her original responses from step 1, she clicked the help button which notified him that step 1 was incomplete. She then redid her response completing all user-input cells and checked herself using the button again and found that her work was now **correct.**

The fourth dimension showed three practices, all of which Azelma gave a rank of 1 as she found them all equal. As a result, no additional user-input cells appeared for steps 2 and 3. Azelma noted at this point that she thought there must be some way to "encode steps 2 and 3 automatically." She believed that this would reduce the ambiguity of the process and the amount of instructions needed. This shows a continued lack of understanding in the true definition of steps 2 and 3 and also identifies two problems Azelma sees with the process. After making this statement she clicked the red button and found that she was **finished with this dimension.**

Azelma continued using the same logic as she had used in the previous dimensions for the rest of the dimensions and **continued to check herself using the red buttons between dimensions.** Azelma put 1 unit of difference as her response for all user inputs for step 2 and continued using the lowest rank for that dimension as her response for step 3. The first dimension was the only which had a maximum rank of 3. No other dimensions used more than 2 ranks, three of which only used 1 rank. Azelma did note that she thought that some practices were ultimately asking the same thing which was why she decided to give them the same rank.

She did not click the green calculation button at the end of the ranking sheet but did do so on the evaluation sheet. Early within the evaluation Azelma made the statement that "if

it's relevant, of course we'll be willing to do it" and that she did not think any of practices would have a willingness of not at all. She later complained that "this is long" referring to the process. With the exception of the first dimension where Azelma gave a few practices a willingness of 3, she rated all practices a willingness of 4. Also notable is that there were four dimensions where all practices were given both a capacity and willingness of 4.

When asked to interpret the radar chart and table next to it, Azelma did note that she had forgotten what the dimensions represented and would appreciate having information about them on the results sheet. Azelma was able to determine that the most relevant thing to her context was the learning phase and also realized that she had a comparatively low maturity score within this phase. Upon analyzing the rest of the results page, she noticed an inconsistency between her evaluation of capacity and the location of the practice within its maturity grid. She later identified that her organization's strengths were in managing the project and acquiring knowledge even during small parts of the project which she believed helped them to continuously improve. She attributed this to technical specialization of organizations involved in the project. Azelma identified a weakness of her network being a lack of knowledge within marketing and logistics as everyone involved in the project, both at her organization and the external organization, had an engineering background. She believed that her organization could improve in this area by hiring people with the needed expertise or by training existing people, but that hiring people would be the easiest. She also thought having contingency plans for when things go unexpectedly during the project would help her personally improve.

Azelma stated that she believed using the tool was "pretty easy," but that the instructions had to be read multiple times to understand it. She found the results section to be the most difficult task as she had trouble correlating her inputs from the evaluation to how the maturity grid showed her results. Azelma found the introduction and context easy and the ranking "a little difficult but okay." Overall, she found that the effort was "not bad" with the exception of interpreting the results. She thought the tool was "pretty useful, " but expected that organizations should already know how they need to improve. She believed the advantage of the tool was that it could help identify things which users were not expecting due to biases relating to expertise or because they were not focusing on the full life cycle of the project. She believed the time needed was reasonable but did not elaborate. When asked how she would use the tool on a future project she stated that it would be more helpful on a "product development-oriented project" rather than a "research-oriented" one. She believed that engineering senior design students could benefit from using the tool. Azelma suggested that the first-time students use the tool should be at the end of a project so that they understand how and why the tool is useful. She believed this would help them successfully use the tool early within a later project. She had no new recommendations for an organization considering to use the tool. Azelma thought that the tool would be the most beneficial if used by mid-sized companies with various teams all working on the same project and that it would be useful to them regardless of if the teams were all from the same organization or not. She noted that a lot of questions were somewhat difficult for her to answer which was why having various teams involved in the evaluation would be helpful.

Azelma felt that learning how to think as her organization as well as how to prioritize actions was something important that she learned as a result of using the tool.

Table 10-1. Azelma Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Azelma	So I'm working on my PhD project which is modeling energy expenditure and recovery in the sport of cycling. So what we are trying to do is come up with – you've seen on your car right? – there is a distance to empty always showing. So we want to come up with something similar for a cyclist. So if you're riding a bicycle at say, 5 miles per hour, if you want to stay at this speed for how long with some reasonable error… so that's probably the spiel of my research.
Liz	**Are you collaborating on this project with anyone else?**
Azelma	Yes, I am collaborating with Dr. V's student F as well as we from Clemson are collaborating with a professor at F University in G-ville. So it's like a 3 way project or something like that.
Liz	**So F is under Dr. V and you're under Dr. M. Is that right?**
Azelma	Yes.
Liz	**Do you have any industries which are involved in the project outside of Furman University or external to Clemson? Any other funding sources?**
Azelma	No.
Liz	**At what phase in this project are you? You can interpret this however you like.**
Azelma	Phase… how do I put this?
Liz	**Are you early in the project, are you already having deliverables?**
Azelma	I'm probably 70% done when it comes to my part in the project, when it comes to F's part I think I would say, he would be maybe 40% done.
Liz	**So is he continuing on after you?**
Azelma	Not necessarily continuing, it's just we have our methods set. He has to validate his method with some more testing. To do his testing we need to do testing from my side of things. So it's like… I come up with an energy model for a person, he uses that in the optimal control algorithm that he has which he came up with to predict somebody's performance on a particular course. So in order to do this my side of things has to be done per person. It's not like a group thing or we're not trying to come up with a model for the entre human population. We are focused on tailor making a model for one person.
Liz	**When did the project start and when is the expected completion date? For the full project for everyone involved. And this can just be an estimate.**
Azelma	I can talk about when I started this project. I started January of 2016 and my part should be done by the end of this year. By December. But I may still be involved in some other testing for Faraz which will probably go into the spring semester. So roughly 3, 3 and a half years, and strictly speaking this project started sometime in 2014 and there has been multiple people working on it so 2014 and 2015 Fall till 2016 Fall, P was working on the same project.
Liz	**Did you collaborate at all with her?**
Azelma	Yeah, so my first semester, she was also a student of Dr. M. We were working on the same project.
Liz	**So everyone involved on the project from Clemson was you, P, yourself, F, loosely Dr. V, loosely Dr. M being advisers on the project and you have the external individual from F University and loosely their adviser.**

Azelma	Yeah, and some undergraduate students from F University. And I think in 2014 there was one undergrad who worked on this project.
Liz	**Was it a creative inquiry?**
Azelma	I think it was a Bachelor's honors thesis. His name was J. But there was no overlap between him and any of us. Except maybe the common factor of Dr. V.
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Azelma	Absorptive Capacity. Is it how much I can absorptive from something? Like say if there is a content given to me like say try to give me a summary of something, so how much I can absorb the concepts which are being given to me. Is it that or something else?
Liz	**I'm not going to answer that for right now. What about the notion of a collaborative innovation network?**
Azelma	I think of it like a large-scale project, like say, people from different backgrounds and domains working together trying to solve a big problem with their own expertise. For example, say, let's take the example of a car. So you'll have people from the electronics side of things and then you'll have the mechanical engineers working on it as well as somebody loading software into the microprocessor or something like that.
Liz	**Have you ever used Simos' method?**
Azelma	No.

Table 10-2. Azelma Scenario Development

Liz	**In this scenario, imagine that one of your research projects – this particularly one you are doing under Dr. M – is the project being worked on. Everyone at Clemson on your research team including your advisers are a part of the SME you are representing – this includes F and Dr. V. Any other industry – namely F University and those from F University – are partners which are involved in your project and are other members of your network.**

Table 10-3. Azelma Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Azelma	So willingness is pretty high. Preparation acquisition willingness is low. And capacity is low in achievement application and learning acquisition.
Liz	**What do those results mean in terms of your project?**
Azelma	So I need to improve, or we need to improve our capacity when it comes to learning acquisition and achievement application and preparation acquisition. The thing is I've forgotten what these are because it's been so long. When I revisit those, I will be able to relate it better to the project's situation. Maybe it would help to give a small spiel of that over here in the results so I don't have to go back and forth maybe. So it shows that based on… so learning from the project is more relevant to the project than the other stuff. Is that right? I'm trying to understand this rubric.
Liz	**How did you come to that conclusion?**
Azelma	Just by looking at the percentages and the relevance to context. I have 91 and 100% on the dimensions where I've scored low. Have I? No… I don't know. So my organization's participation is more when it comes to learning acquisition and learning assimilation and low when it comes to achievement application. That's what I'm trying to understand, within the collaborative network that is. My contribution, or my organization's contribution towards the project is more the learning side of things, reflecting on the project. And how I can make use of that as opposed to the other two domains.
Liz	**Next, analyze the other figures underneath for each dimension. Describe their general meaning. You don't necessarily have to greatly interpret each one but…**
Azelma	So you're always looking for a high maturity score I'm guessing. So there's 1.2 to improve. Is it capacity of 1 and willingness as 3? So I understood this thing, the importance. So the most important is listed at the top in decreases levels of importance. So I would understand this: I need to focus more on this? If I'm guessing right, but if it's not important to me then why would I focus on it? I'm trying to understand what this is trying to tell me.
Liz	**Please identify an area of strength. Something you're good at.**
Azelma	Maybe when it comes to acquiring knowledge and managing the project, learning from say, small phases of the project or stages of the project and how to kinda go back, basically iterate the process and constantly improve. So I think it could be one of the dimensions which is involved, the preparation and the application, oh the achievement phase.
Liz	**What do you think is the cause of this strength?**
Azelma	The competencies, the biases that my organization has. We notice that we don't have – for example in our project – we don't have knowledge about the health sciences. We're more the engineering side of things, so we try to acquire that knowledge and then see how we can apply that to the problem. How we can use that and build something based on that.
Liz	**Can you identify an area of weakness? And then what do you think will be the cause of this weakness?**

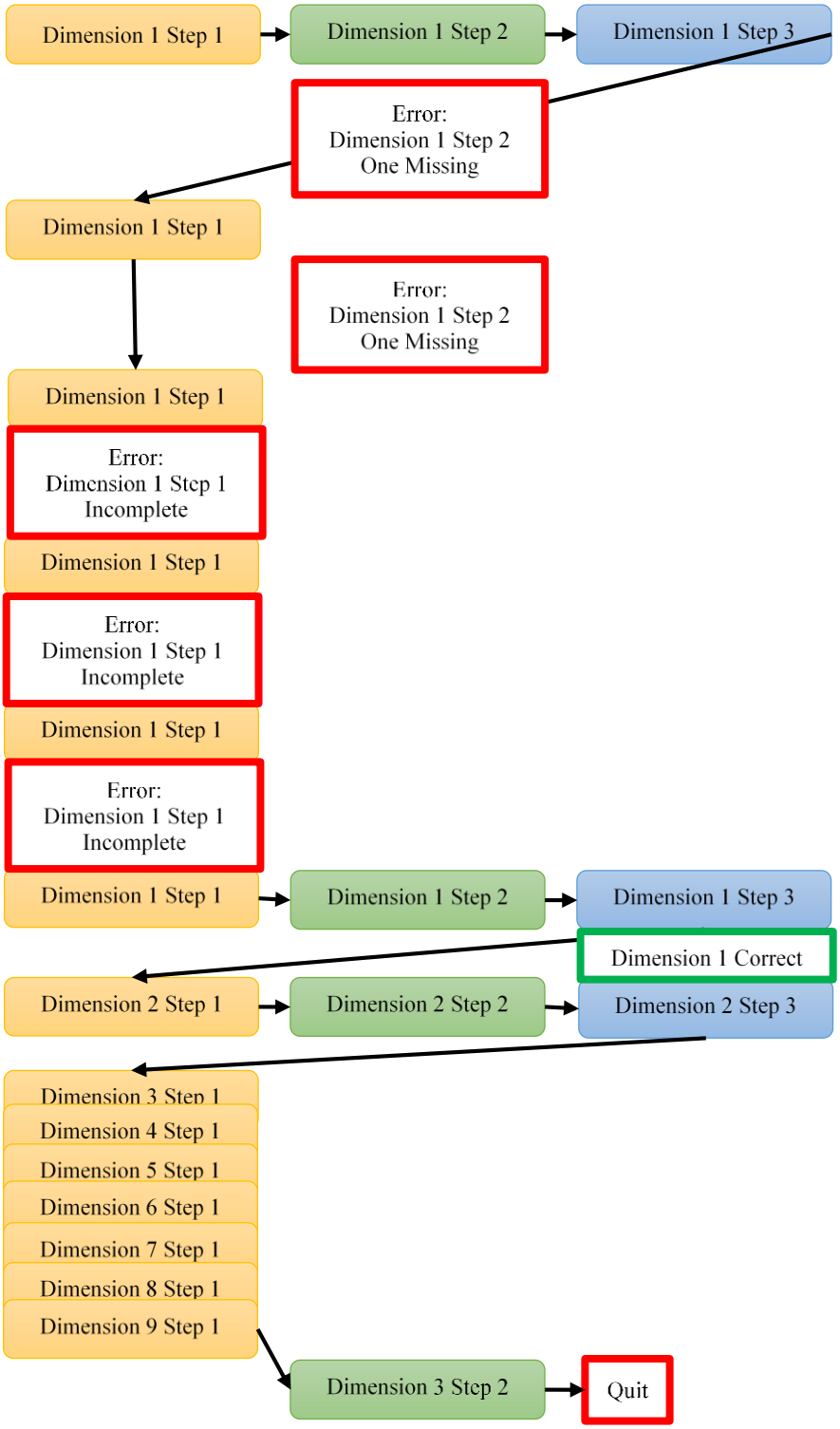
Azelma	So an area of weakness would be how to manage the market, like say, the business side of things, cause we – all of us are engineers – and even the people working in the health sciences, the professor whom we collaborated with, he is also an engineer. He did his PhD in bio-engineering. So we're not well-versed with the marketing side of things or maybe the logistics, say. If whatever we're doing becomes a product which needs to be marketed in a certain way, branded or whatever that is, all the things associated with a successful product, that would be a weakness. We are strong when it comes to the technical side of things but not maybe the marketing or business side of things.
Liz	**What action would you recommend that your organization take to improve in an area where it is weak?**
Azelma	What actions we can take? We can hire people with those expertise or we can get trained on those things. So it depends on what we want to do. Probably the easier thing to do is hire somebody who is good at it. The difficult thing is maybe to train people.
Liz	**What action would you recommend that you specifically take to improve in areas where you or your organization may be weak? These aren't necessarily all the marketing stuff.**
Azelma	Maybe following the schedule better. Well again it has a lot of variables and a lot of delays. You plan for something and not everything single time does it work out that way. So we probably need to build in contingencies and learn to do that so there will be less frustration. That's something I would personally like to improve, maybe planning better.

Table 10-4. Azelma Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Azelma	It was pretty easy. It was long but it was okay. If an organization was investing money into this they would be willing to go through this ordeal. If they deem it to be helpful. It's pretty easy, it's not difficult. If you read the instructions twice. That's the most important thing, reading the instructions properly. Because there's so many things going on. You read it the first time, then you kinda think you know it and then you have to go back and revisit all those things. Maybe it was stupid of me to ask you a few times, but you weren't allowed to guide the person doing to study so… it was pretty easy.
Liz	**Which parts of the tool were the most difficult and why?**
Azelma	The last results section, I don't know, maybe I'm just incapable of understanding what's going on here, the grid. I'm still trying to understand what was going on because you say the importance you gave them, it's highlighted in green so I think all the important stuff is going to be in the green. And for 1.2, capacity was 3 but it seems like it factors it in like capacity was 1 here so I don't really understand what's happening. It was also hard to understand the graph and the relevance to context.
Liz	**Which parts were the easiest and why?**
Azelma	The introduction. The context was pretty easy. The ranking, a little difficult but okay. I think I figured it out. So you think of highest and lowest. Do you think about it based on the number like highest is 1, lowest is 3, so if you do highest over lowest you get 1 over 3 so I was a little confused. The most difficult was trying to understand the evaluation or the results I think.
Liz	**How do you perceive the amount of effort needed to use tool?**
Azelma	Physical, not much. When it comes to cognitive effort, overall, not bad. It was okay, it was not too bad. Except the results thing.
Liz	**How do you perceive the overall usefulness of the tool?**
Azelma	It seems to be pretty useful. Based on the evaluation of their own organization, it'll kinda tell you, ok, this is what you need to improve on. So you kinda know the answer. So you're addressing many issues here. You kinda subconsciously maybe know what you need to improve on but when you put everything together it may be different from what you initially thought of so that might be eye-opening for the end user. Because we have our own biases and these questions cover the entire spectrum of the project so you're trying to answer questions based on experience pertaining to every single phase of the project so… I think this is more elaborate and you probably… there's a possibility someone might be surprised saying "oh, I did not think about this at all" or "I missed this completely." So I think it has the potential to be very useful.
Liz	**How do you perceive the amount of time needed to use the tool?**
Azelma	So it's different for different people. You had given me a time of two hours and I think I finished it in roughly 90 minutes because we started at 2:15, 2:20 and it's 1 hour and 45 minutes, it's pretty okay.
Liz	**If you used the tool for a future collaborative project, any project, when during the project would you use it and how?**

Azelma	If I had to use this thing, I would probably use it on a project which is not research oriented. More like a product development-oriented project. I would use it on that, like maybe an ME402 project. It would be really helpful to give this to 401 students and ask them to go through this. If you could have the same project teams use it for 401 and 402 whether they are willing or not. In real life you don't get to choose right? So you'd have the same set of 4 or 5 people working on a 402 project. At the end of the 401 project you can make them do this and see how they do it and then give it to them at the beginning of the 402 project. That was at the end of 401 they could say that this could be really useful on a more serious project in 402 where they will probably use it earlier. It doesn't have to be the same teams, it could be individuals and you could probably compare 3 or 4 individuals doing it and then maybe you might look at how you can put two people together based on this response.
Liz	**What recommendations would you offer an organization considering to use this tool?**
Azelma	Like I said, this could be really useful. An organization generally knows what it needs to improve on but sometimes it might not be aware, it might have missed a few things. So this is really detailed and really captures a broad spectrum so it might find things they might have missed and that is pretty valuable.
Liz	**What characteristics would an organization need in order to maximize their benefit out of using this tool?**
Azelma	So you hit a lot of aspects like business, supply chain, logistics. So if there's a small company and only one person doing it that would not be very helpful, but say if that person was collaborating with somebody else… maybe if they were mid-sized companies. They'd need to have different teams working on a project. So the characteristics an organization would need is one, different departments or different teams working together towards a common goal. To use this tool within an organization you could treat different teams as different organizations which could be really helpful. I think that's the most important characteristic they would need to have different teams working together. Because a lot of questions are kinda hard to answer.
Liz	**Are you thinking teams from 1 organization or multiple organizations?**
Azelma	It could be both. So if it's just one organization, let's say Lenovo, they may have a software side group of people, that's a team, and then maybe the engineering people who communicating with these people about what they need, and then maybe the marketing people, so there's all these different kinds of teams could be treated as different organizations.
Liz	**What would you say are the most important things you learned from using the tool today?**
Azelma	To read the instructions carefully twice. And putting myself as the organization working on my research project and trying to think of the most important things that need to be done, so if I'm to take something back from this, if I were to work on a big scale project in the future, I would probably go back to these things and how would I deal with these things and how the organization I'm working for deals with these things. That's probably the most beneficial thing for me.

Baptistine


Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Error:
Dimension 1 Step 2
One Missing
Dimension 1 Step 1
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Dimension 1 Step 2
One Missing
Dimension 1 Step 1
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Incomplete
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Dimension 1 Step 2
Dimension 1 Step 3
Dimension 1 Correct
Dimension 2 Step 1
Dimension 2 Step 2
Dimension 2 Step 3
Dimension 3 Step 1
Dimension 4 Step 1
Dimension 5 Step 1
Dimension 6 Step 1
Dimension 7 Step 1
Dimension 8 Step 1
Dimension 9 Step 1
Dimension 3 Step 2
Quit

Baptistine was a non-native English speaker and Master's student. She has some idea about the meaning of absorptive capacity but knew nothing specifically about the notion of a collaborative innovation network. She had also never used or heard of Simos' method.

Baptistine's scenario was based on a research project she was working on with industry. Her project involved using a manufacturing simulation environment built at ICAR to measure the effects of audio and visual distractions on assembly associates during production. The project appears to be exploration-driven with no specific applications of the findings identified during the interview. The project as she sees it involves herself and two other Clemson Mechanical Engineering graduate students, a Mechanical Engineering faculty from Clemson acting in a mentor role, as well as an Automotive Engineering faculty from CU-ICAR. Although the project was funded by industry, Bapstistine was not familiar with any collaborators from this company directly involved in the project. The final scenario that was developed was that she would represent her team at Clemson while CU-ICAR and the company funding her project would be her partners. Notably participant Fantine was one of her collaborators on this project at Clemson.

She was given the concise version of the tool. Compared to other participants, Baptistine very quickly conducted her initial review spending less than a minute on the task. During this review (4m 31s), she noted feeling somewhat overwhelmed with the color usage throughout the tool stating that "it's a little too many colors." She had no other feedback other than that nothing else stood out to her.

Twelve seconds into her readthrough of the introduction (7m 24s), she asked the meaning of the acronym "ACAP" however six seconds later she was able to find her answer

within the tool's text. A while later (7m 54s) she also asked the meaning of SME. This information had already been discussed following the script but was not included within the text of the tool. I chose to identify this information for her within the script. She was slightly confused why her scenario involved imagining BMW as an SME when the tool's text stated that large corporations could also benefit from using this tool. This was due to my own error during the development of her scenario as I should not have identified BMW as an SME but simply as a network partner. The effects of confusion due to this error may have caused some frustration. She also stated that she was confused (9m 17s) about what made up the "nine dimensions of ACAP." Baptistine understood that there were three phases and that these phases had what she called "sub-phases," but did not verbalize how this related back to "dimensions." She also noted confusion on why collaboration would stop and was not sure at what point it started. This may stem from understanding the "phases" as "ACAP phases" rather than "project phases." She also exhibited some frustration due to my not being able to answer her questions though she was encouraged to keep asking them. Upon reaching the information on the "Project Context" step (11m 36s) of the process she paraphrased the text slightly and asked whether she was "rating how much [she] agreed with certain statements" for this step. She was again denied an answer. Eight seconds after this denial (12m 1s) she complained that "this seems a little complicated." However, upon reaching information about the "Results" she commented (12m 27s) that she thought that "This is cool, the maturity scores." Upon completing her review of the introduction, she suggested that she will need to figure it out as she goes and that she felt like there was too much information.

Early within the context sheet (13m 28s), Baptistine noted that she did not like abbreviations and thought the tool would benefit from avoiding them. Soon after making this statement (13m 52s) she returned back to the introduction sheet due to confusion, but she did not verbalize what she was hoping to find. She can then be heard (14m 7s) reading "External environment… In your organization's sector of activity the level of technological intensity is high…" and then immediately asks if this was referring to within her project or within her organization. She was prompted to refer back to the instructions but upon returning to the statement (14m 30s) Baptistine still had the same question. She referred to the instructions again for a second time and concluded that it was referring to the project. When evaluating the "frequency of innovation" she can be heard saying that "within the project, so-so, but with the industry not really. But I'm evaluating the situation." At this point she gave the statement a 4. She then pondered the "level of competition" statement noting that there was no competition within her project and gave it a 5. She then realized that 5 was strongly agree and had to reevaluate her previous 3 responses. She noted that she was expecting 1 to represent "strongly agree." She appears to correctly use the scale for the scale from here on out verbally indicating agreement with statements she gives high values to. Upon reaching the "partner organizations on the project" list of statements she can be heard saying that "there are no partners." I intervened at this point and reminded her than for her scenario that industry B as well as the faculty at CU-ICAR were both partners within her network. She then asked "Isn't B the organization?" implying that she was imagining herself as the industry funding the project rather than as her research team at Clemson University. No intervention was made at this point. She then stated again that she

was confused and struggled to identify a partner on the project. After a few moments of complaint, she can be heard saying "Oh, Clemson! Alright. This thing is very very very very not clear" (18m 52s). She does not return to her previous responses suggesting that she has identified Clemson as her partner organization and that she is continuing to see herself as the company funding her project. Upon reaching the "organization structures and/or work cultures" context statement she states that "Oh, I need to revisit everything because this is asking about your organization and I did it thinking about… Whatever." She appears to continue using the scale correctly for the remaining statements and then returns to the statements involved in the "role in the project." After rereading parts of these statements she can heard saying "I need to change everything" (20m 42s) seemingly in exasperation. She quickly changes a few of her responses.

Immediately after being prompted to begin the ranking process, Baptistine complained (21m 24s) that she didn't think she could do it because there was too much information and things to process. She eventually gives up trying to process the instructions and states that she will just learn by doing it (22m 11s). She then verbalized confusion about the meaning of "ranks must be consecutive and/or same rank" pertaining to step 1 of the process. She continues to read and reread the headers and states (22m 36s) that she does not understand the process and "feels dumb" indicating frustration. Eventually she decides to start with step 1 of dimension 1. Upon reading the first practice (23m 49s) she notes that she is also frustrated with the wordiness of the statements. She also does not understand why there is a space between practices (due to irrelevant practices being hidden) but initially choses to ignore it (23m 59s). She correctly ranks the practices and completes the

other steps for dimension one, however when she clicked the validation button she was given an **error message because she had not properly defined the smallest difference between ranks as 1 unit for step 2.** She reads the message to herself which does indicate that the problem occurred in step 2, ponders the message for a few seconds, and then indicates that she does not understand. She instead decides to change her values for step 1 and then clicks the button again. As she had not changed her response for step 2 **she gets the same error message.** She complains about the white space between practices again (25m 1s). She ponders for a few more seconds and then states that she thinks she knows how to fix the problem. "I think I have to put it here and not here" referring to where she had put her ranking values for step 1. She attempts to put values in the non-editable white cells directly below each practice, is not able to, and then puts her responses within the editable white cells within the user input column of step 1. Baptistine clicks the validation button and now gets an **error message that step 1 is incomplete.** She then asks (28m 8s), "Am I doing this wrong? I'm obviously doing this wrong." She laughs at herself a bit and clicks the validation button again getting **another message about step 1 being incomplete.** At this point she states that "I don't know how to do this. I give up." She is told that she is allowed to give up if she chooses however after a few seconds (26m 39s) she determinedly states that "No, I'm not giving up; I never give up." and is allowed to continue. She complains again about the many colors of the headings and the white spaces between practices (26m 51s). She states again (26m 58s) that "I feel dumb but I did read the instructions." Baptistine then refers back to the instructions and asks "What does this represent?" referring to the number lines within the example. She thinks a bit longer and

can be heard scrolling throughout the sheet and then states (27m 34s) not referring to a specific part of the process. She continues putting numbers in white cells, reads the header for step 3 and indicates confusion. She now puts numbers in all cells within the user input column for step 1 including those formatted as user inputs and those left as white. She clicks the validation button (28m 14s) and for a third time gets an **error message about step 1 being incomplete.** Baptistine reacts by saying "They have all been ranked!" She continues troubleshooting and after a few seconds (28m 48s) states that "I don't know where to put my ranking." She deletes her ranks and then reads aloud from the instructions (28m 10s) "Confused? Need help? Click the nearest button… no, I already did that." Baptistine asks "Where do I put my ranking?" and I responded by asking her to read the instructions fully to which she responded with "But I did!" She does, however, refer back to the instructions. Baptistine can be heard reading (29m 32s) "If there are no user input cells no action is required… wow." She verbalizes frustration and then complains that the images used underneath this statement do not clearly convey the information. Baptistine then adds (30min 19s) that "It just took me 20 minutes to figure that out" when in actuality only 9 minutes 7 seconds had passed since the start of the ranking task. Baptistine attempts step 3 of dimension 1 again and can be heard reading and rereading the header and instructions pertaining to it. She then asks herself "Is it 3 divided by 1?" seemingly basing this off of the rank numbers she gave her highest and lowest ranked practices rather than their amount of importance relative to each other. She then clicks the appropriate button (31m 25s) and is notified that the **first dimension is correct and complete.** She celebrates

and also mentions the amount of time she spent on the task. She will not click on any additional validation buttons for the rest of the task.

At this point Baptistine begins the second dimension. She asks (31m 38s) if the dimensions should be considered separately or not. There is only one rank shown for this dimension to which she gives it a rank of 4 implying that she is using the same ranking scale she used for dimension 1. As a result, the sheet offers ranked pairs up to rank 4. Baptistine indicates all of these pairs as equal to one unit. She then puts a value of 4, equal to her lowest rank, as her response for step 3. Baptistine does not click the button to check her work before moving on to the next dimension.

Baptistine continues onto dimension 3 where 9 practices are shown. Upon reaching step 2 (34m 0s) she is confused why she is asked about the difference between ranks 1 and 2 when she had – incorrectly – not given a practice a rank of one within this dimension. She opts to skip steps 2 and 3 of dimension 3 (35m 32s) after stating that she had "no idea how to do step 2."

Baptistine then completes step 1 for dimensions 4 through 9 using only ranks 2-6 for all practices. She is mostly quiet while she does this. Roughly 4 minutes later (39m 26s) she can be heard reading a header for step 2 but it is unclear which dimension though it is assumed to be dimension 3. After another minute of silence (40m 31s) she is prompted to speak aloud. Baptistine states that she is confused by the meaning of units of difference between 1 and 2 and does not understand what the 1 and 2 are referring to. When she had completed step 1 for this dimension previously she had erroneously not given a practice a rank of 1 so the sheet was mistakenly showing her illogical extra user inputs for step 2

causing her confusion. As she never clicked on the validation button for this dimension she was not aware that step 1 was done incorrectly. For the four pairs of ranks shown for dimension 3, she gives the first three pairs one unit of difference and the last pair 0. At this point (41m 35s) Baptistine is asked if she wants to give up or continue. She explains that she does not understand step 2 but does not indicate that she wants to give up. I later step in and give her three options: (1) continue trying to figure it out, (2) give up and I can explain how to do it, or (3) skip the task entirely and move on to the next task (43m 16s).

Baptistine chooses option 2 and I proceed to guide her through how the ranking process working. At this point we modify the tasks so that she only has to complete the first dimension for the ranking and evaluation sheets as this was the only dimension she was able to validate before intervention. This means that she will only get results for this first dimension. The radar chart will not be interpretable, and the scores will not be able to be compared to any other dimension, however capacity and willing for this dimension are still comparable. She may also be able to get some meaning from the maturity matrix and practice importance within this dimension.

Baptistine now completes the evaluation for dimension 1 is able to determine that she will need to click the green calculation button at the top of this sheet before continuing. After reading through the instructions (48m 15s) she states “Ok, I can do this.” Similar to how she felt about the scale used for the context sheet, she notes (48m 32s) that she feels the scales are numerically inverted from what she was expecting. She otherwise completes the evaluation for the first dimension without further comment, although notably she put 4 for all of her responses. This means that both capacity and willingness for this dimension

will have perfect scores and that all practices will be in the green region within her maturity matrix though they will have various amounts of importance.

When asked to examine the radar chart and table she identified that "acquiring to prepare" was a strength. I mistakenly skipped prompting Baptistine to analyze the other parts of the results and instead proceeded onto the scripted results questions, therefore all of her responses can be assumed to only be based off the radar chart and maturity score table. She identified that she thought that her team's knowledge background, past research, and review of literature was the cause of her strength in both capacity and willingness to do practices within the preparation acquisition dimension. This dimension also had a low context relevancy percentage which she believed indicated a "bad result." She disagreed and thought the relevancy should be higher. She believed that her team spent a lot of time preparing and learned a lot from their projects but was probably weakest on the application side due to certain obstacles. She thought putting pressure on industry to apply their work might help them be more successful.

Baptistine discussed that she thought the introduction could be more concise and mentioned that she thought the scales used within the context and evaluation sheets seemed inverted. She notably discussed these rating scales as "ranking." She discussed that the ranking was the most difficult, in particular step 2. Baptistine blamed lack of clarity in the instructions, example figure, and user input prompt phrasing for step 2 for her confusion as she did not understand what she was comparing. She felt that the context, evaluation, and results were clear. The identified the context and evaluation as being particularly concise and to the point. Baptistine reiterated that she found the color usage throughout the

sheet overwhelming. She thought the tool required a lot of effort and time but that it could be useful if you can actually get results. Baptistine mentioned that the results are incredibly subjective. She felt that the tool would be best used at multiple stages within the project to compare the phases to note progress within the application dimensions. She would not recommend the tool be used by an organization before the ranking section was made clear. Baptistine believed that organizations with team-based projects would benefit the most from using this tool but that any organization would at least get some benefit. The most important thing she felt she learned from her time using the tool was the importance of keeping things simple. At this point she also mentioned that "If it wasn't for the purpose of this I probably would have given up immediately because it's just not worth the time to spend this long on figuring it out."

Table 10-5. Baptistine Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Baptistine	Right now I working on the B cognitive load project. We're introducing new technologies to this project cause it's a project that already started last semester. So we aren't only using the EEG but also a heart rate monitor and some way of tracking the eyes but the aim is to discover what kinds of distractions the associates go through during the assembly line. We're going to first do an audio experiment and then a visual experiment and then a team, two people assembling something.
Liz	**Is this using the assembly takt platform at ICAR? The platform that moves?**
Baptistine	Yes.
Liz	**I was on that project way back when. So who all is involved in this project?**
Baptistine	C, A, and I.
Liz	**Are your faculty all somehow involved in the management of the project?**
Baptistine	Dr. S but he's more of a mentor.
Liz	**Are there any industry sponsors?**
Baptistine	BMW.
Liz	**Is there anyone else outside of B? Other universities maybe?**
Baptistine	No.
Liz	**Are there any students from ICAR involved in this?**
Baptistine	No.
Liz	**Are there any faculty from ICAR involved in this?**
Baptistine	No. Well, I think Dr. M is but not directly.
Liz	**At what phase in this project are you?**
Baptistine	The beginning.
Liz	**When did the project start and when is your expected completion date?**
Baptistine	I'm not sure when it started. I know H and D were working on it last semester in depth. The completion is probably next semester. At the end of next semester, the end of May.
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Baptistine	The capacity to absorb… a concept? No, I'm not.
Liz	**What about the notion of a collaborative innovation network?**
Baptistine	I can assume, but no.
Liz	**Have you ever used or heard of Simos' method?**
Baptistine	No.

Table 10-6. Baptistine Scenario Development

Liz	**In this scenario, imagine that one of your research projects – specifically this project with BMW – is the project being worked on. Everyone at Clemson on your research team including your advisers are part of your SME. Anyone at ICAR would be another SME, and BMW would be considered an SME. I realize none of these are really SMEs but for the sake this tool they are.**

Table 10-7. Baptistine Results Interpretation

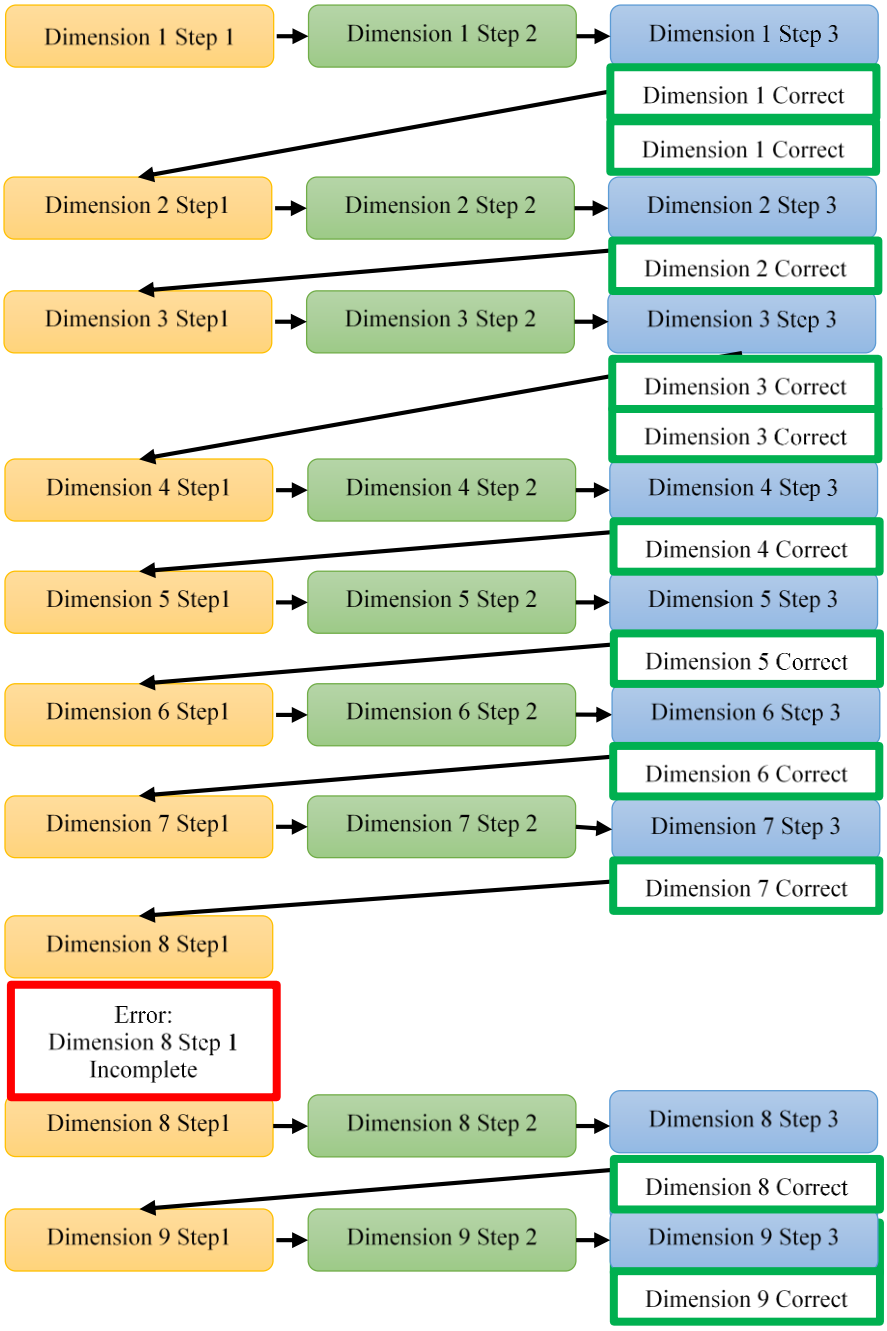
Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project. I realize that we definitely shortened yours, but we're going to continue. Be an honest as you can but I realize the context of what I'm asking you to do. So, read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Baptistine	So I'm just looking at the first one right?
Liz	**Yes. If you'd like you can also consider the relevance to context on the far right. You can ignore your zero scores on that. So to reiterate, examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Baptistine	So my organization is capable of acquiring to prepare, I guess? I don't know.
Liz	**Can you identify an area of strength? This does not necessarily have to be a particular dimension. Can you identify an area of strength and what do you think is the cause of this strength?**
Baptistine	I mean, I think the knowledge is the cause of the strength. The preparation acquisition, the capacity and the willingness. Because of the background knowledge that we need and all the research that we do. The literature review and all that stuff. I think that's one of our strengths.
Liz	**Can you identify an area of weakness? What do you think is the cause of this weakness? Based off of your results or based off of your process of using the tool, can you identify a weakness? To your project.**
Baptistine	The relevance to context, it's 30% which isn't high. So I guess that's not a good result? I'm assuming, I don't know. What is the relevance to context really? I mean, I get it, but 30% is not a high number I assume that's not a good result even though I do think my project is relevant to its context.
Liz	**What action would you recommend that your organization… these questions may be difficult but bear with me. What action would you recommend that your organization take to improve in areas where it may be weak? Not necessarily this weakness that you just identified.**
Baptistine	I think within the preparation. I don't like our weakness. We do a lot of the preparation. We achieve what we want but in the end…but the application… and we learn from it but the application itself is always tricky because you can't always apply it. You have a result but… either you can't apply it because it's an industry project or you can't apply it because… various reasons.
Liz	**What actions would you recommend that you specifically take to improve in areas where you or your organization may be weak?**
Baptistine	Based off of what I just said, try to actually apply it and make sure that it's applied. For example, what I'm working on, if we do get good results maybe try to push it to get it applied.

Table 10-8. Baptistine Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Baptistine	So it depends which section. The introduction was a little too wordy honestly and maybe it could be more straight to the point. But it was good. And the context was fine. I was just confused on the ranking. And the scales, it should be flipped in my mind. And the ranking, this is just mind blowing. It's not clear at all. This is what confused me. We went on the evaluation and that part was very straight forward, just rank them even though the ranking should be flipped in my mind. But in the end it's pretty clear what to do. But the ranking, first of all, why do you have these blank sections. Those made no sense to me. And second of all, I don't understand the units of difference between 1 and 2, between 1 and 2 what? 1 and 2 ranks? I need a describing word saying what 1 and 2 are. I feel like this doesn't portray the importance – the figure – it doesn't portray what it should portray. I feel like there has to be a better way of showing this. And then this is straight forward – step 3 – once you know this it's fine. The second step is just very confusing.
Liz	**What parts of the tool were the most difficult and why?**
Baptistine	The ranking was the most difficult, especially step 2. I think the instructions weren't clear enough, honestly. The image wasn't clear enough. And then step 2. It says "define the smallest importance difference between the ranked pairs as 1" which I understand this but then it says "this unit is redefined for each dimension", what dimension? And then "units of difference between 1 and 2," ok, 1 and 2 what? It's confusing.
Liz	**Which parts were the easiest and why?**
Baptistine	The context. The evaluation. The results are pretty clear. The context is just, bam. This is what you have to do, do it. It's short and straight to the point. The evaluation is the same. I said it before but I think all these colors throw me off. Too many colors. Especially in the ranking section. It's just way too colorful. I get so confused.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Baptistine	It's a lot of effort. A lot of effort for the ranking, honestly it blew my mind. I walked into this thinking it was pretty easy especially when you go through the context. I think that it's pretty straight forward so then moving on to the ranking is a shock. It should be more clear.
Liz	**How do you perceive the overall usefulness of the tool?**
Baptistine	I think it's very useful. I think the results, if you actually get results, could be very useful. But they are very subjective. But it maps out what you want to see in relation to the maturity scores and the percentage of relevancy even though I do think that relevance to context doesn't really show what it is. But in general I think it's useful.
Liz	**How do you perceive the amount of time needed to use the tool?**
Baptistine	I think it's too long. This ranking section is too long. It should be compressed and straight forward just like the other sections.
Liz	**If you used the tool for a future collaborative project, when during the project would you use it and how?**

Baptistine	It depends on what I want to look at. I would probably use it throughout the project. At multiple stages. Why? Because I'd want to see each section, the preparation, achievement, and learning. I would want to see the results based on those. So at the end of each section if that makes sense, because I'd want to see if at the end of preparation if the application wasn't there then I would want to do something about it.
Liz	**What recommendations would you offer an organization considering to use the tool?**
Baptistine	I wouldn't recommend it until the ranking section is clear.
Liz	**What characteristics of an organization would they need to maximize their benefit from using the tool?**
Baptistine	I think team-based projects. Every organization can benefit from this but the way to use it is what is challenging and that's challenging with every tool.
Liz	**What do you think are the most important things you learned from using the tool today?**
Baptistine	Keep it simple. If it wasn't for the purpose of this I probably would have given up immediately because it's just not worth the time to spend this long on figuring it out. So that's why I think that that section should be much easier and more straight forward because otherwise one just gets frustrated with it.

Cosette


Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Dimension 1 Correct
Dimension 1 Correct
Dimension 2 Step1
Dimension 2 Step 2
Dimension 2 Step 3
Dimension 2 Correct
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Dimension 3 Step 2
Dimension 3 Step 3
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Dimension 5 Step 3
Dimension 5 Correct
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Dimension 6 Correct
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Error:
Dimension 8 Step 1
Incomplete
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Dimension 9 Correct

Cosette was a native-English speaker and Master's student. She had some knowledge about the meaning of absorptive capacity potentially from a previous presentation I have given on the topic but was not familiar with the notion of a collaborative innovation network. She had never used Simos' method before.

Cosette's scenario was based on a creative inquiry research project she helped lead with the help of a Mechanical Engineering faculty. It involved about 20 undergraduate students mostly from Mechanical Engineering split into teams working on similar projects with different sets of requirements all for the same industry sponsor. In reality this sponsor had no collaborative input on the project minus supplying information on the problem and some basic requirements but was included as part of Cosette's collaborative innovation network anyways.

Cosette was given the concise version of the too. During Cosette's initial review of the tool, she noted (5m 5s) that the tool suggests that collaboration stops at a certain point in the project which she disagreed with based on her own experience stating that collaboration "goes on for as long as possible." She mentioned that she thought the color coding helps. Upon reaching the context sheet (7m 16s), Cosette indicated that she liked how the boxes organized things and noted that she expected to put responses in the orange user input cells. Cosette then navigated to the ranking sheet (8m 16s) where she had to scroll up to the top saying "this is a long page." When checking out the figure on this page (9m 7s) she noted that she found the arrows confusing. She was curious as to the reason for the empty white space within each dimension (9m 47s). Cosette later noticed (11m 26s) that one practice had already appeared within one dimension. She was able to conclude that the reason it

appeared was probably because she was going to need to rank it later. She did state (12m 33s) that "they all look the same pretty much, all the different sections. Once you get the hang of it, it seems like you could use it pretty easily." Cosette also noted seeing the green button and realized this would need to be clicked "when you finish everything." Upon reaching the evaluation sheet, she noted that she liked having the green button on this sheet as well in case you forget. Cosette thought (13m 18s) that the evaluation tab seemed more straight forward and notably mentions "ranking" rather than "rating" on this sheet. Upon reaching the results page she noticed that one relevancy percentage was above zero but did not know why and also found that one practice already had an importance percentage which caused her confusion. Cosette also noted the formatting, lack of instructions, and header title typo within the plan of action sheet.

Cosette was the first participant to have the workload evaluation as part of the study. Her prompt for the introduction differs slightly from future participants which may have affected her initial perceived workload levels. She was told "Please proofread this sheet. Check for any language discrepancies or if something seems unclear or irregular. Let me know what you find and when you are finished." Future participants would instead be told to "read for understanding" and that I would ask for a summary when they are finished to allow them to better prepare themselves for the second part of the task. During her proofreading of the introduction she did not notice any errors, although no typos or grammatical errors were expected. Following the protocol used for all participants which were given the workload evaluation during their studies, Cosette was asked to give a summary of what she had read. She described that the phases each had different steps which

had different tasks within in them specific to the phase and noted (24m 56s) that she had focused more on the language and not specifically on the information. At this point she is prompted to complete the workload evaluation and is provided definitions for each of the forms of workload. She indicates that performance had the greatest impact on her experience of workload followed by frustration and mental demand.

Cosette now begins working on the context sheet (31m 22s). She verifies that she is supposed to be thinking as her research team which I do choose to confirm (31m 35s). She can be heard thinking aloud about how she is coming up with her responses, indicating higher values for ones she agrees with and lower for ones she disagrees with. Cosette mentions (33m 36s) that she sees her project's target market as the company also acting as a collaborator on the project and that involvement with them is expected more during later parts of the project. Despite her own leadership role on the project, she notably verbalizes (33m 56) that she believes that her organization is not very involved in the management of the project as they "just follow the rules." Upon reaching "initiate strategic internal changes," she mentions (34m 52s) that she does not think that it applies and gives it a 1. She later asks (35m 13s) whether the final section involving her organization's "position relative to partner organizations on the project" was supposed to refer to her organization versus company N. I refused to answer so she indicated that this was how she interpreted it.

Cosette now begins the ranking process (35m 47s). About 2 minutes later (37m 33s) she can be heard mentioning the practices and saying that she is a bit confused about she is supposed to be doing. She later summarizes what she thinks she is supposed to do before

she begins (38m 6s) saying "I'm supposed to rank the list of practices by order of importance." She later adds (38m 18s) that "Consecutive rank required, same rank allowed. That's a little confusing. It wants us to… but you can do one, one, one if you want." She peruses the example figure and notes (38m 48s) that the arrows do not make sense to her, however soon after she can be heard muttering "ok, I get it now." Cosette adds (39m 12s) that she does not know where the practices came from and asks if they are referring to the practices that her organization does. She begins narrating her thought process regarding her responses and can be heard referring back to the instructions to verify her understanding for step 2. Based on her narration, Cosette does appear to understand step 2 as early as the first dimension. For step 3 it is unclear if she chose the value 3 due to the number of the lowest rank or because she genuinely thought the first rank was three times more important. When finished with the first dimension (42m 13s) Cosette clicks on the validation button and is notified that **"ACAP Dimension 1 is correct"** however she states that she does not know what this means. She chooses to click the button again (42m 29s) and concludes that she must have completed this first part right. Before proceeding onto the next dimension she mentions that she does not understand why some rows are empty, however she suspects that it may be related to her organization's "situation." She does not specifically mention the context sheet but does suggest that she would prefer if the practices would all be grouped together.

Upon reaching the second dimension, Cosette found only one dimension and can be heard saying (43m 7s) "There's only 1 so it's got to be 1. Unless I'm supposed to compare between all these different sections. I don't think I am. I'll check." At this point Cosette

uses the validation button and **finds that she did it correctly,** so she seems to have confirmed her assertion that she should rank sections independently.

She begins reading through the practices for dimension 3 and notes (43m 38s) that there are a lot more practices this time and reiterates that it would be helpful if they were all together. Cosette continues reading through the practices and about a minute later (44m 31s) reiterates that there are a lot of practices and that she feels like it is more difficult to figure out the ranking. Cosette also comments that to rank things you need to know a lot about the items already which makes doing this difficult for her as this is the first time she is seeing these practices. As she completes the ranking she narrates her thought process, indicating (47m 12s) that she sees some practices as very similar and is choosing to have them at the same rank. When she reaches step two for this dimension she comments (49m 48s) that this part makes more sense for situations where there are a lot of practice because it does more to set the scale. Upon reaching step 3, Cosette decides (52m 26s) to check the instructions again to better understand the scale she was creating but noted that referring back to the instructions did not actually help her much. She settles on a value of 5 which is notably different from her lowest rank of 6. She then clicks on the validation button and finds that she has once again **done it correctly.** Cosette chooses to **check it for a second time** to see if the message will change but finds it to still indicate that she has done the dimension correctly.

Cosette begins ranking the practices for dimension 4. She is satisfied (52m 39s) that the three practices shown are grouped together. She comments that she is not sure why the practice numbers start at 4.3 though she does relate it to the fact that the first practice is in

the third row. Upon completing the dimension Cosette continues using the validation buttons to check her work.

Cosette follows the same seemingly correct logic for dimensions 5 through 9 checking her work with the validation buttons as she goes. She notices (57m 12s) in dimension 5 that one of the repeated headers was still in French. Having never previously received an error, at dimension 8 (1h 7m 37s) she tests the capabilities of the tool by clicking the validation button before she has entered any ranks. The tool of course notifies her that step 1 for this dimension is incomplete. Satisfied she continues with the ranking process for the rest of the sheet clicking the green calculation button (1h 12m 50s) when she is finished.

Cosette then begins working on the evaluation sheet narrating bits and pieces of her thought process. Part way into her evaluation (1h 15m 16s) she comments that "it helps having the scale right here" referring to the scale frozen at the top of the sheet.

When asked to interpret the results, Cosette struggled to related it back to specific aspects of her project which most of her responses being a bit vague. She mentioned that she felt like the radar chart and score correlated with her responses but that she did not understand the meaning of the relevancy percentages. Upon looking at the maturity grids and importance lists she commented that she believed that the relevancy percentages must be connected to the importance percentages shown here. She was able to identify dimensions of high and low willingness and capacity using the radar chart and scores but tended but did not show a clear understanding of what these dimensions represented. Cosette showed no inclination to interpret the importance percentages. Cosette identified that communication was a strength of her organization due to their openness to new

information. She thought that a weakness of the team was that they do not purposefully look for information outside of their team, however she also stated that her team generally did not need to because her team was self-sufficient and was so good at sharing knowledge within the team. Cosette made no specific recommendations for improvements her organization could make but thought the charts could help identify where they may be lacking. She found it easier to determine action she specifically could do. Cosette believed that she, as one of the organizers on the project, could step in and push her team members to pull in more external sources. However, again, she previously expressed that doing so was generally not needed on her project.

Cosette is once again prompted to complete the workload assessment. She indicates that mental demand is now the largest contributor to her experience of workload with effort and performance as runners up. Noticeably her overall workload is 17 points less than it was after the introduction.

Cosette is finally given the standardized debriefing interview. Despite having very early-on correctly figured out how to use the tool, she indicated that she felt it was too hard and that she was not confident in her interpretation of it. Cosette identified the ranking process as the most difficult. She reiterated that she thought that since this was the first time she was seeing these practices that she found them hard to rank. She found the evaluation process was the easiest but used the work "capability" rather than "capacity." When asked about the amount of effort, Cosette indicated that it was "a decent amount of effort" but that it was justified to get meaningful results. She believed that investing the effort to accurately do the ranking process was particularly critical to how much she would

trust the results or see them as "worth it." Cosette discussed that she had been a little skeptical about the usefulness of the tool in the beginning but having seen the results now thinks it seems "fairly useful." She did not find identifying strengths as particularly beneficial, but thought that identifying areas of improvement could be. Cosette believed that the amount of time required was unrealistic to expect from someone busy working at an organization, but that "if you have the time to do it, it might be worth it." She believed that the tool would be most useful during the "middle stages." Based on her comments she seemed to believe this was because the tool was somehow easier to use if you had already done some of the practices. Cosette recommended that if an organization chooses to implement the tool that they should train people on it first to avoid making it unnecessarily hard or take more time than it needs to. She briefly alluded to the fact that she felt that the research focus of her project made the tool less applicable to her case, however she felt that an organization working on a more design-based project with the goal of coming up with new solutions, technologies, or ideas could benefit from using the tool. The most important thing Cosette learned was the knowledge absorption practices themselves however the reason why is unclear.

Table 10-9. Cosette Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Cosette	I'm not really working on any research projects at the moment. I'm in the process of figuring out my research project.
Liz	**Are you an RA at all?**
Cosette	I'm a TA.
Liz	**Aren't you working on that creative inquiry project H used to work on?**
Cosette	Yes.
Liz	**Can you describe that project for me? Are you still involved?**
Cosette	No, I'm just leading it.
Liz	**So in that sense, you're still involved.**
Cosette	Yes, I'm still involved. So that project is a collection of challenges from company N. So there are four teams in my class and each team has selected one of the three challenges. I think I said four, but it's only three this year. So they are problems that the company N teams came up with typically related to the space station.
Liz	**Is that related to the freight farms project at all?**
Cosette	No, it's specific. So our goal is to design a tool to solve one of their problems and it's really open ended. They give you a list of a few requirements and the teams are supposed to come up with their tool solutions over the course of a year.
Liz	**Who all is involved on the project with you? You said you had a leadership role on the project.**
Cosette	So I'm organizing the class. So I tell the students what they should be doing through the design process. It's me and Dr. S and we take turns telling them what to do. It's a group of undergraduate students. I think there are 20 students who are all Mechanical Engineering with one Geology major.
Liz	**Is this a project which is collaborative with any outside organizations? With N or someone else?**
Cosette	Yes, so the project is sponsored by N but they don't have any real input.
Liz	**At what phase in the project are you? I realize this is somewhat a bunch of mini projects going at once.**
Cosette	The idea is that they all go at the same pace. We're at the beginning. We're on the requirement generation and primary solution generation and ideation.
Liz	**When did the project start and when is the expected completion date?**
Cosette	It started the first week of September and it's expected to finish the end of May.
Liz	**So it's a two semester long project.**
Cosette	Yes.
Liz	**Are you familiar with the concept of Absorptive Capacity or ACAP?**
Cosette	Maybe.
Liz	**Maybe? What do you think it might be?**
Cosette	I think it's amount of information a person can take in.
Liz	**Where do you know this from?**
Cosette	Just context clues.
Liz	**Were you at my presentation a while back?**
Cosette	The CEDAR one? Yeah.
Liz	**What about the notion of a collaborative innovation network?**
Cosette	No.

Liz	**Have you ever used Simos' method?**
Cosette	No.

Table 10-10. Cosette Scenario Development

Liz	**In this scenario, imagine that one of your research projects is the project being worked on. In this case this would be your project with company N. Everyone at Clemson on your research team, including your advisers are a part of the SME you are representing. Any other industry partners which are involved in your project – namely company N – would be other members of your collaborative innovation network.**

Table 10-11. Cosette Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Cosette	I'm looking at the general trend of this radar chart and looking at the numbers on the table. It looks like we have pretty high willingness and capacity in most areas. There's some lower capacity in preparation application and achievement application. And there's a little bit lower willingness in the preparation assimilation areas and achievement assimilation. But in the learning section, both are pretty high. So looking at the numbers, it's kind of confirming what the chart is showing. So I think it means that for our project specifically we like to use that knowledge that we gain from external sources to improve ourselves and learn from it. The assimilation, taking what we know and using or taking what other people know and using it. We have 100% relevancy there and 100 and 98 capacity and willingness scores. So the relevance to context, I don't really know what it means. I don't really know why the numbers are different. Because we have for learning assimilation 100 and 98 and 100% relevance but we have 96 and 100 for preparation acquisition with a 30% relevance. I don't know where that relevance comes from. But for the maturity scores and the graph they make sense based on the answers I gave previously based on our capacity and willingness to do certain things within certain areas of this process.
Liz	**Next, analyze the figure under each dimension. Describe their general meaning and explain how you would interpret them.**
Cosette	So it looks like it uses the same data but presented a different way. And I see the importance now. Maybe that's where the relevance numbers came from, from before. Going to the first section. I see the different importance. I can't really tell the difference between some of these numbers based on this graph.
Liz	**Can you explain how you would interpret these?**
Cosette	Yeah. So I guess what I would do is I'd probably cross check it with willingness and capacity. I can't tell if these are supposed to be different or if they're all in the same area. But it seems like all of these are threes in willingness and threes in capacity giving them a high overall score. I would probably look at those different things and then these percentages. It looks like they are just rated by importance.
Liz	**Can you interpret the meaning of that first one in context of your project?**
Cosette	I would take it as we know how to and we're willing to prepare for our project. Before we actually start, looking at what we need in order to succeed. It looks like we're in that medium high range, we can and want to do this. Finding out what we need to know before we begin.
Liz	**Can you identify an area of strength?**
Cosette	I'd say an area of strength we have is our communication. We do all the things that apply to that. That's what we focus on in our project.
Liz	**What do you think is the cause of this strength?**
Cosette	I'd say our openness to new information of everyone on the team on the project. By being open to learning we can increase our skills of sharing that knowledge.
Liz	**Can you identify an area of weakness?**

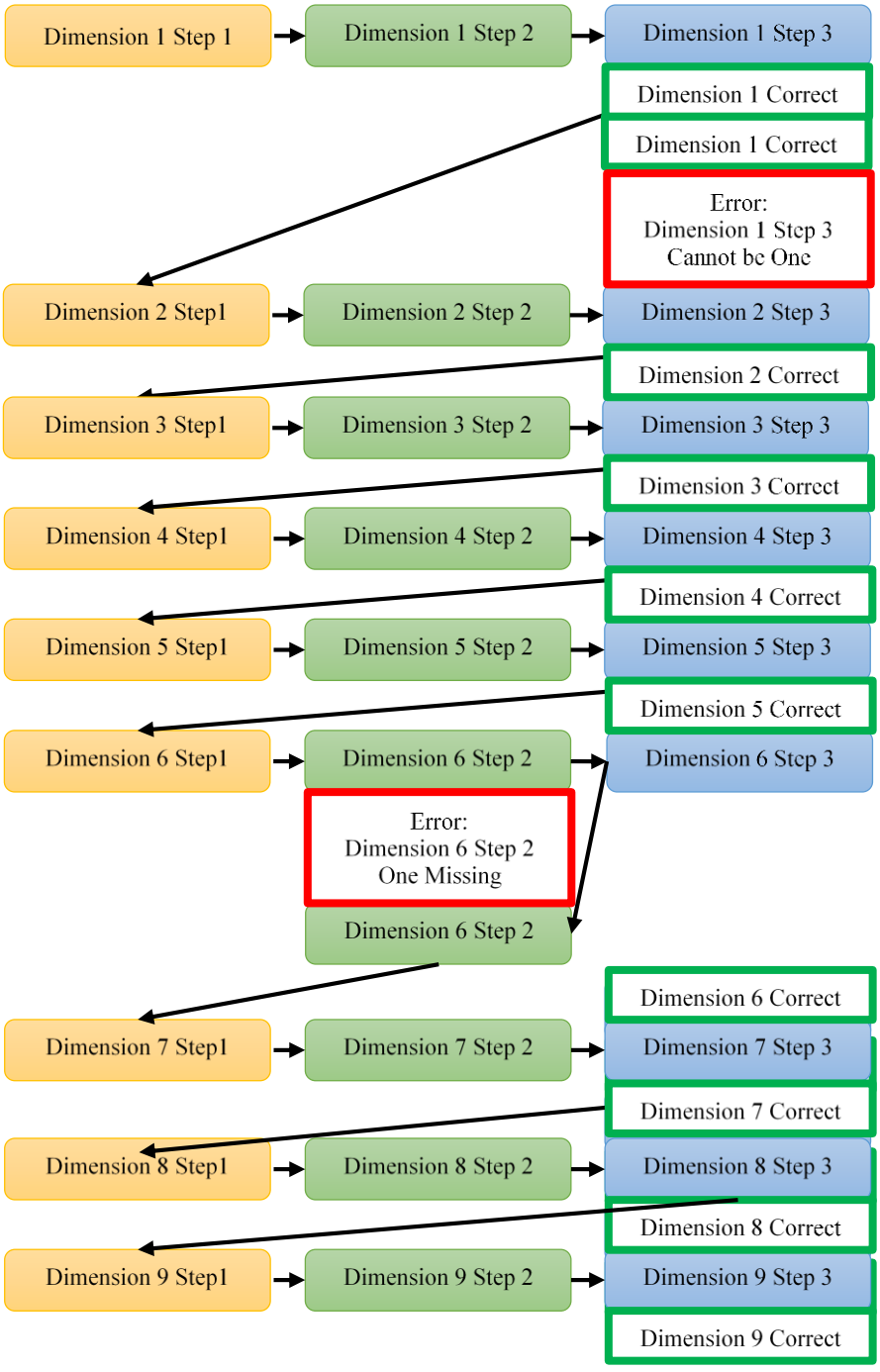
Cosette	Probably going external to our team. We do a lot of internal work checking with the other organizations as needed. But maybe we can use external resources to increase our productivity.
Liz	**What do you think is the cause of this weakness?**
Cosette	Not necessarily needing to use external resources. We can find what we need internally. But I'm sure we could improve by going externally.
Liz	**What actions would you recommend that your organization take in areas where it may be weak?**
Cosette	We could go analyze these charts and see where we're lacking and where we're not capable of doing certain things or maybe where we're not willing to change, maybe look at what we should be more willing to do and what we should learn how to do so that we're capable.
Liz	**What actions would you recommend that you specifically take to improve in areas where you or your organization is weak?**
Cosette	So I guess as the organizer of our project I can take that step and provide the teams with more of a direction in our weakness areas by going externally.

Table 10-12. Cosette Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Cosette	So I think some areas were more easy than others. It was a little too hard to figure out how to use it I guess. I don't know if I did it right, but the way I interpreted it just took a little bit of… read the instructions, look at one of the areas you had to fill out, and then after the first form, you get the hang of it, at least what you think you're supposed to do.
Liz	**Which parts were the most difficult and why?**
Cosette	I thought the ranking of importance was the most difficult. I mentioned earlier that seeing these practices for the first time, before this I wasn't thinking about doing these things. Seeing them for the first time and having to rank them first of all in order of importance and then differences in importance was hard.
Liz	**Which parts were the easiest and why?**
Cosette	I thought the capability and willingness was pretty easy. That was just "do you know how to do it?" and "Are you willing to do it?" You can look at it and think about what you can and cannot do.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Cosette	I think it's a decent amount of effort. In order to get good results out of it you really have to think about each answer, specifically that importance part. If you don't get that part really right, you don't really know if those results are worth it so you do have to put that effort into making sure you do it correctly and accurately.
Liz	**How do perceive the overall usefulness of the tool?**
Cosette	At first I was a little skeptical, but looking at these charts and the results it does seem fairly useful. Maybe not for what you're already good at. It does tell you what areas you're good at. But areas you can improve, you can learn and adapt from what you're lacking in.
Liz	**How do you perceive the amount of time needed to use the tool?**
Cosette	I know people probably wouldn't like to spend and hour and a half, two hours, doing this as they are busy working. So if you have the time to do it, it might be worth it. But I know for many people it's probably not ideal.
Liz	**If you used the tool for a future collaborative project, when during the project would you use it and how?**
Cosette	I think I would use it during the middle stages when you've been working on the project. So some of the questions were "have you used knowledge that you gained from this thing." At the beginning you might not have tried to gain that knowledge yet so if you do it in the middle, maybe early middle. You have gained some knowledge already and you can use it to see what you need to do going forward before you get to the end of the project.
Liz	**What recommendations would you offer an organization considering using this tool?**
Cosette	I would recommend that whoever is in charge of giving this out to really know what they are doing so that they can explain it. You can train people how to use it. Because if you just take this thing and send it out without really training people on it, it might be too hard to use and take more time than it needs to.

Liz	**What characteristics of an organization would they need in order to maximize their benefit from using the tool? Who are the ideal organizations? What do they look like?**
Cosette	So I think they are more design based. Research isn't so… People who are trying to come up with new solutions for things because a lot of these are based on gaining knowledge from external places, the internet, other people, conferences, the other company and look for new technologies and new ideas.
Liz	**What are the most important things you learned while using the tool today?**
Cosette	I learned about the different practices that these organizations do or that we do. It might be important to note those before having to do these tools. Be aware of what you are doing and how you can use those to see what you're lacking in and see what you're good at already and try to maximize your performance by coming up with new ideas.

Dahlia


Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Dimension 1 Correct
Dimension 1 Correct
Error:
Dimension 1 Step 3
Cannot be One
Dimension 2 Step1
Dimension 2 Step 2
Dimension 2 Step 3
Dimension 2 Correct
Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Dimension 3 Correct
Dimension 4 Step1
Dimension 4 Step 2
Dimension 4 Step 3
Dimension 4 Correct
Dimension 5 Step1
Dimension 5 Step 2
Dimension 5 Step 3
Dimension 5 Correct
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Error:
Dimension 6 Step 2
One Missing
Dimension 6 Step 2
Dimension 6 Correct
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Dimension 9 Correct

Dahlia was a native English speaker and Master's student. She was not familiar with the concept of absorptive capacity as it is used in the tool, however she able to provide a fairly accurate definition of a collaborative innovation network. She had never used Simos' method.

Dahlia's scenario was based on an investigative project that she was working on with a precast company. Although still a member of Clemson University, as a part of the project, Dahlia was also embedded at the precast company to learn more about their manufacturing environment and identify opportunities for improvement which would become additional future projects. One of these areas that the company wanted Dahlia to look into was in implementing 3D printing technologies into their manufacturing process. She was working closely with two employees of this company: a continuous improvement director and a lean coordinator. Dahlia was also being advised by two Mechanical Engineering faculty from Clemson University. She discussed that there had been a previous 1 year contract which had ended in August 2018 which had lead to the work she was doing now. Her project and 1-year contract had begun August 2018 and would continue until August 2019. Additional contracts are expected to stem from her work and last for a couple more years.

Dahlia was given the concise version of the tool. During her initial review of the tool she mentioned that she did not recognize any of the logos but did notice that one of them was French. Dahlia noted (6m 40s) the color usage took a moment to process but otherwise had a positive view of it. She also commented (6m 57s) that she did not find the introduction to have an excessive amount of material, however compared to the other sheets she found (7m 40s) the ranking sheet to be rather large and difficult to view on her

laptop screen. She indicated confusion about the white space on the ranking sheet where practices were not being shown. Upon reaching the evaluation sheet she quickly noted (9m 29s) that the sale stayed frozen and that she liked this feature though it was still difficult to view on her laptop screen and she found it distracting. Immediately after clicking on the results page (11m 10s) Dahlia can be heard saying "Oh, that's cool" referring to the radar chart which she compared to similar charts used within behavioral research. She also noted that she also liked the graphics showing how to interpret the bottom half of the results page and that the formatting here worked better for her screen size. On the plan of action sheet, she noted some formatting improvements that could be made.

Dahlia was asked to review the introduction and that she would need to provide a summary at the end. She indicated that she felt they were clear but would prefer acronyms – such as ACAP, CIN, and SME – to be defined before they are used (17m 32s). Later (21m 23s) she located a vague usage of the word "you" in the introduction's description of who is being evaluated. Her summary of the introduction included who uses the tool and why. She chose to relate the tool back to the company where she is imbedded.

When she was done giving her summary she was then prompted to complete a workload assessment of the task (23m 37s). She indicated that she felt the mental demand contributed the most to her experience of workload, though she believed frustration was the most important factor compared to the others. Her second and third most contributors were effort and performance.

Dahlia then launched into completing the context task. She commented (28m 11s) that she did not know the definition of "concurrence" off the top of her head. She later discusses

that she is doing her evaluation imagining herself as the company she is embedded in and not as Clemson University. At the end (30m 47s) she can been heard saying "I am done with the context ranking – scoring I mean."

During Dahlia's initial review of the instructions for the ranking sheet, she commented (31m 13s) that she was a bit apprehensive when the first thing she read was "Confused? Need help?" She later suggested that rearranging the order of which the items within the instructions were presented may be more logical. Upon reading the instructions for step 2 for the first time, Dahlia indicates that she did not understand them. She spends a bit more time reading the instructions and processing the example figure and eventually states (33m 47s) "I'm confused but I'm going to just go ahead and focus on step 1 for right now because trying to move ahead and read about step 2, I am already lost." Dahlia also commented (34m 44s) that she felt the practice wording could be made more clear by indicating who was doing these tasks, though she did realize it was referring to the organization she was representing. Later (35m 47s) Dahlia discusses that a few practices must all be rank 1 but then reads that practices must be consecutive or same rank which she indicates she does not understand. She adds (36m 12s) that she realizes that the empty spaces must be practices which are not applicable but that there is not anything to tell her this and as is, the sheet appears broken. She then correctly completes steps 2 illustrating that she understands that one of the differences must be 1 but that not all differences have to be 1. When completing step 3 for dimension 1 she asks whether she needs a calculator to figure this out. She assumes not and chooses 7 as her response and **validates her work** using the button. To learn more about the tool she changes her response for step 3 to a 9 and

revalidates and finds that she is **still correct**. Then she tests a value of 1 and gets the **corresponding error message.** She changes the value again to a 2 and finds upon clicking on that button that the dimension is **correct again.** Dahlia changes it back to 7 but does not revalidate.

She completes dimensions 2 through 5 without any errors following the same logic as the first dimension **checking that her work is correct with the buttons** as she goes. When completing the 3rd dimension (43m 48s) she comments that she is getting lost in the terminology trying to consider so many practices and notes the amount of time she feels she is spending on them. She adds that she feels the terms are "managerial." When completing step 2 for this dimension (45m 17s) she discusses that she is making it easier on herself by simply putting one for every unit of difference for this dimension. Between the 4th and 5th dimensions Dahlia scrolls to the bottom of the sheet and back up to see how much more she has to do and comments "Wow, there are a lot of different sections to rank." Within the 5th dimension Dahlia also notices (49m 5s) the header still in French.

Upon clicking the validation button for dimension 6, Dahlia is notified (50m 37s) that **there should be at least one difference for step 2 equal to 1 unit.** She quickly adjusts her answers and **revalidates** (50m 48s). She then previews the evaluation sheet (50m 56s) to appraise how much further she has to go before quickly coming back to the ranking sheet. She notes that the amount of practices is variable and that she wishes that there was an indicator saying how many practices were within each section.

She completes dimensions 7 through 9 **continuing to use the validation buttons** as she goes. At the very end she also clicks the green calculation button.

Dahlia then began working on the evaluation (56m 5s). She complains amount the large amount of space she feels that the green button at the top of the sheet takes up, particularly since it was already included on the previous sheet. She adds that she feels like the number of items does not feel as bad for the evaluation, though she realizes this may only be because the font seems smaller. She initially decides to complete all the capacity column and then return later to complete the willingness column however soon thereafter Dahlia can be heard completing both columns for at least some practices. Later (1hr 0m 55s) she comments that "I'm getting fatigued trying to evaluate and process these at this point." Further on (1h 5m 1s) she complains again that "I'm even struggling to stay focused." Upon completion of the evaluation (1hr 12m 31s), Dahlia asks whether she should click on the calculate button again. She indicates that she is afraid of losing her data if she clicks the button again so she makes sure to save beforehand. She does decide to click it again though it has no effect.

Dahlia is now prompted to interpret her results from the radar chart and table. She notes that her network is doing poorly based on the way she scored them, however identifies several of her lowest scores as being "pretty good" or "not too bad" noting that she does not see any terrible scores. She then summarizes which areas she thinks she needs to focus on identifying achievement assimilation, learning application, and preparation acquisition which had her 3 lowest scores for either capacity or williness. Notably preparation acquisition was the weakest in capacity but also the strongest in willingness though Dahlia did not specifically assess this. After being prompted to analyze the result of the results, Dahlia generally ignored the importance of practices. She did comment that the importance

percentages varied but were usually low compared to the relevancy percentages and thus she did not feel that they were significant to consider. She also attributed her lack of motivation to analyze the results further to the fact that she felt her scenario was hypothetical. To determine a strength of her company she quickly identified a practice within the green region of a maturity grid and then related it back to her project. The practice was only of medium importance compared to other practices though this was not mentioned by the participant. Dahlia explained that this strength came from the fact that employees at her company could easily communicate with their supervisors to enact changes related to training. Dahlia identified the fact that employees do not regularly participate in conferences as a weakness of her organization. She noted that the reason for this was that her company would not be willing to share patentable information, especially with competitors, unless they felt morally obligated to do so as they might about work place safety related improvements. She added that her company had problems getting her software licenses so she was struggling to access archived information needed for the project directly, though she was able to still get this information with the help of colleagues. Dahlia also felt that her role on the project was being the liaison between her company and Clemson University, therefore she thought she could improve by determining an effective way of communicating weekly progress to everyone involved in the project.

At this point, Dahlia was asked to complete a workload assessment. Workload was noticeably higher for all measures with the exception of performance compared to Dahlia's initial workload. The most significant workload was due to mental demand and temporal demand.

During Dahlia's debriefing interview, she discussed that she felt the tool was generally self-explanatory but did rely upon assumptions being made. She thought the validation button were not particularly useful. She found length to be the aspect of the tool which made it difficult, particularly within the ranking and evaluation. Dahlia found the context sheet to be the easiest due to it being straight forward and not requiring much time. She complained that she felt the ranking took 30 to 45 minutes to complete, though in actuality is took just under 25 minutes. She felt that the mental effort was partly due to having to process the managerial vocabulary of the tool. Dahlia added that switching from an easy to complete process to a more complicated process was a bit of a shock. She suggested that using the tool in short increments would allow people to get more use out it by helping them avoid mental fatigue and giving them more time to absorb. Dahlia discussed that the tool became "painstaking halfway through," particularly the ranking sheet. She stated that "I definitely see the tool as taking too long to want to use." She felt that the tool was the most useful before or immediately after kickoff in the project so that the results could be used to communicate the weaknesses of partner organizations. Dahlia believed that a project manager or someone involved in the coordination of the project should complete the evaluation but did not identify any organizational characteristics which would help maximize the benefit out of using the tool. The most important thing she felt that she had learned was that her organization had some areas of improvement within their collaboration methods and file sharing.

Table 10-13. Dahlia Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**

Dahlia	I work for a precast company through a contract with Clemson and Dr. T so we're looking for productivity improvements there on the site primarily to do with computer aided design and computer aided manufacturing. Things like "do we do laser projectors, do we 3D print materials." And we're still working on the creative inquiry that I started in undergrad which is robotic agriculture so we're looking at 3D printing hardware and novel application of it to use in the garden for horticulture.
Liz	**Which of those projects would you say you are the most familiar with?**
Dahlia	Well I've been on the farm-bot project for a year, I've been embedded at the precast facility for a month.
Liz	**Let's go with the precast project. So for this precast project, who all is involved in this project? I know you mentioned two faculty involved in the project.**
Dahlia	Dr. S and Dr. T both visited company M previously to get the contract signed. Company M is the precast company in Greenville.
Liz	**Are they collaborating with you on this project?**
Dahlia	Yes, so it was actually them who brought me out to look for opportunities there. We're not sure what opportunities we're pursuing yet but right now it's to look and see how the operation is working at this point.
Liz	**Is there a particular type of project that you are doing even if it isn't fully fleshed out yet?**
Dahlia	They would like to look at 3D printing some of their block-outs for their precast which are basically inserts that you put in so that when you pour concrete you have vacancies in the piece.
Liz	**So they don't necessarily know how they are going to go about doing it but they know they are interested.**
Dahlia	Right, I'm working with their continuous improvement director for their corporate office and I'm also working for their lean coordinator on site.
Liz	**Are there any other companies involved in this project besides company M and those at Clemson?**
Dahlia	No.
Liz	**At what phase in the project would you say you are?**
Dahlia	We're at the kick-off phase basically. We're at the phase where I'm inserted into the plant I'm in observation mode to see how things are done so I can get more of a broad overview and not just a snapshot of how most of the processes are done at the plant to see if we can identify opportunities.
Liz	**When did this project start? I know this project is rather early so it may not have an expected completion date but if you could estimate it for me.**
Dahlia	This phase of the project was contracted for 1 year. They closed that contract in May or June I believe. The end time of this phase of the project would be August. We kicked it off in late August. My first day of employment there at the plant was August 20th. According to Dr. T they expect the contract to be extended into an actual development and roll-out phase. By the end of the first year we will have fleshed out some long term projects that could take multiple years to fabricate for example. It just depends upon what direction we go. He's expecting it to take more than 1 year. Like 2 or 3 maybe.
Liz	**Are you familiar with the concept of absorptive capacity?**

Dahlia	What comes to mind for me is batteries, capacitors, and mechanical devices which store energy like thermal batteries or hydroelectric for example.
Liz	**What about the notion of a collaborative innovation network?**
Dahlia	I would assume a network of people not necessarily in the same area maybe in different disciplines or cross disciplines that would have some means of saying "hey, this is what I'm working on, can we work on this project together" across distances and across disciplines.
Liz	**Have you ever used Simos' method?**
Dahlia	Never heard of it.

Table 10-14. Dahlia Scenario Development

Liz	**In this scenario, imagine that one of your research projects is the project being worked on. For our sake, we're going to use your precast project that you're working on. Everyone at Clemson on your research team including your advisers are a part of the SME that you are representing. Any other industry partners involved in your project would be considered other members of your collaborative innovation network. You are being your lab and your advisers and your partner is this other organization.**

Table 10-15. Dahlia Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Dahlia	So the way I scored myself, our network kind of sucks. In terms of high relevancy, I'm noticing that our most mature areas such as achievement application capacity 85 willingness 86. Relevancy is 30%. Whereas learning assimilation we're 73, 75, and 100%. That's actually pretty good. 69, 68 on learning acquisition. I'm not seeing anywhere where it's a terrible score. I see the lowest score here is a 57. Yeah, 57, 57, relevance to context is 67%. So actually not too bad. Looking at the graph I see the white lines which I assume are part of the graphic and not the blue and the red lines which are the active graph. It makes me want to read those as something even though it's just an octagon or heptagon or whatever nine is.
Liz	**Nonagon.**
Dahlia	A what?
Liz	**Nonagon.**
Dahlia	Nine-agon?
Liz	**Nonagon.**
Dahlia	Nonagon, okay.
Liz	**Next, analyze the figures underneath for each dimension and describe their general meaning and explain how you would interpret them.**
Dahlia	So we're pretty strong is achievement application and learning application is going to need work in terms of capacity. So our capacity and willingness is very weak when it comes to achievement assimilation and learning application and preparation acquisition. So those are areas we need to focus on.
Liz	**To reiterate, analyze the figures underneath for each dimension and describe their general meaning and explain how you would interpret them.**
Dahlia	So to emphasize while the numbers themselves aren't very representative of anything like 1.10 or 1.9 that we have capacity and willingness for at least 3 items in the preparation phase. We've got some immature items, two of them, and three that are sort of in the middle leaning towards have capacity issues, not willingness issues. So those are just labels of those different items and behaviors. 6% importance item 1.10. I have to visually search for it again in the heat map. So I guess if I was using this as a management tool I would see 1.2, so I would say we're really good at exploring supply chain knowledge, we're good at staying informed using other organizations, and we are good with using experts. And we need to focus on participating in scientific or industrial – No we don't. I told you that it's not applicable here but… I understand. Alright preparation phase, so we got two items. One is reasonably mature, one is immature and that's organization communications. So we need to get better at communicating with the organizations. So essentially we're really good at involving ourselves because we are the client. But, communicating with other people in the CIN, we've got work to do on that. Preparing for application we're actually pretty solid on. We don't have much willingness on a couple of these items. 3.1, 3.8. But we can do them. And then you have some immature items, 3.6, 7, 9, 5. Ok, I can see why those aren't numeric order. Ok, I am bugged out by the way it's very noticeable on the preparation for application of external knowledge section isn't in any sort of numeric order. So 3.6

	was defining the evaluation methods for the innovation because we're looking to identify opportunities and we don't know what those are yet. I don't know if we know how to set parameters for that. 3.7 is collaborative tools, 3.9 innovation business model, 3.5… acquisition of external knowledge. I haven't even been paying attention to the importance scales honestly. So up here you showed your relevancy to context scores and they were high, down here we're looking at importances that range from 3% to 12% a lot of the time. Sometimes 50%. I guess I'm not getting anything useful out of that but I like the fact that those are scored. Other than that this seems like a lot of information that at this point in the tool, having put all the information in, I'm kind of drained to the point where I don't really want to pour through the results data. Also because we're talking about a hypothetical situation so there isn't a tangible motivation here so I'm not motivated get any useful results out of this since its all made up.
Liz	**Please identify an area of strength.**
Dahlia	We're on item 9.6. Establishes the means for promoting the application of new knowledge, so training people on how to use a new layout tool for a new precast concrete piece maybe.
Liz	**What do you think is the cause of this strength?**
Dahlia	So within the company if they were to say "we're bringing in this new laser overlay technology so people know where to put down rebar." It's a case of them being able to go to their supervisor and say "here's the new technology, we're going to be using it" and then they can easily incorporate regular training sessions into that and it's just really easy for them to incorporate it.
Liz	**Can you identify an area of weakness? What do you think is the cause of this weakness?**
Dahlia	Sure! Like the conferences we were talking about. Or wanting to go to conferences but that is based on this is an industrial application, this is not an open-source collaborative application. So if we do find some very patentable improvement technology for the production side of things it will not be, by definition, shared with other companies, especially other competitors. Unless it relates to work place safety or something, something where there's more of an ethical obligation to share. But if it's just we know how to make this cheaper than everybody else…
Liz	**What action would you recommend that your organization take to improve in areas where it may be weak?**
Dahlia	Well let's look at data sharing. So an example, I've been contracted to be on the site and look at their computer aided drafting and computer aided drafting. But I have not been given software license access. So for the software they use on the site I cannot personally get on a terminal and access it. They could certainly make some efforts to give me a workstation with proper seed access and everything else. As well as let Clemson into a certain database of files because they want me to be able to look at different reports and different materials to say these are the different opportunities that we've identified in the past, this is all the research that we've done on them, and these are our findings. And I don't have computer access to those files on those networks which have been archived somewhere to say "yes, we've looked at laser projection technology in the past and this is what we found out." So right now I have to ask others to access these files and every time we find something

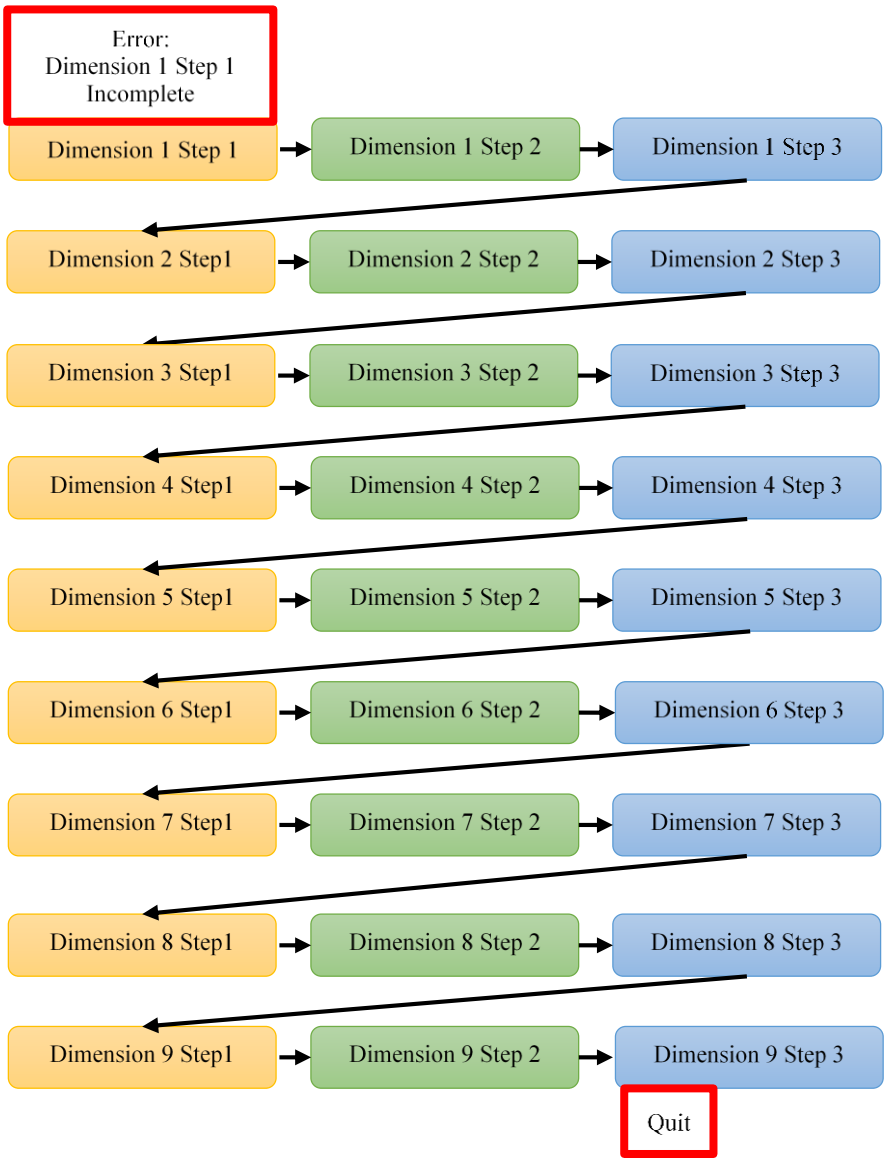
	interesting I have to ask them to email one or two of them to me each time. I can't just pour through the data myself.
Liz	**What action would you recommend that you personally take to improve in areas where you or your organization may be weak?**
Dahlia	Maybe on scheduling and on coordinating meetings with Clemson University for example. So I'm the middle person on all this, as well as the other research student we haven't named yet. So it's kind of up to us to bridge communications fluidly with Clemson and company M. So we can certainly do that by way of our weekly meetings, my adviser meetings, we can do that as an email chain, as a message board, as a conference call, I don't know that we'd do it as a conference call, but just trying to keep everyone involved well informed as to what is going on. Coming up with some vehicle for saying "this is what's been done in the last week since our last meetup."

Table 10-16. Dahlia Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Dahlia	I mean, you didn't have to jump in to explain a whole lot. So it was fairly self explanatory. It did require sometimes making assumptions. Because we were talking about, I think we were on the evaluation screen, no the top of the ranking screen, where we talked about how the first thing I should see is step 1, step 2, step 3 and not the "confused" header or the instructions or example header. I didn't really get that much use out of the instructions. The first bullet point with the X and the check mark, I didn't see that anywhere else so I didn't know if that was relevant. I guess limitations of Excel. That help/check correct button, I guess it helps but I don't see the usefulness of it except that it isn't going to crash your calculation macro. But it is a pretty self-explanatory document. Even if it was a bit frustrating to get pin-balled back and forth. And there's some inconsistent formatting, for example on the evaluation page and having the big green calculate button hanging out there taking up screen space. Yeah, it was easy enough to pick up with the guide there.
Liz	**Which parts of the tool was were the most difficult and why?**
Dahlia	Probably in terms of length, it would honestly have to be the ranking. Either the ranking or the evaluation just because of the amount of time and really getting lost mentally in all these different words running together. Collaboration innovation project, organization, were just thrown at you so often that your brain becomes soup trying to contextualize it all in your head to give the practice it's actual rankings. So those were the hardest parts to use. Not even the calculation side of it but the textual parts of it and processing what's being asked and relate that back to arbitrary numbers.
Liz	**Which parts were the easiest and why?**
Dahlia	Probably the context page. Very straight forward. You could get that done in 3 or 4 minutes. The results page was also fairly straight forward although it of course provides more information and would be backseat to the context page. And it was actually weird to get from a short context page like that to very long pages of ranking and evaluation. You're adequately prepared for the short ones because you're thinking "oh this will be easy" in the context and then you go to ranking and it takes you half an hour, 35, 45 minutes to complete, that and the evaluation.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Dahlia	There's no physical effort. Mental effort it's trying to unblur sentences together and make sense of managerial action verbs like organization and collaboration. But not that difficult, except at first it was really difficult to process the ranking system at the top. That was confusing. And I had to make a lot of assumptions to move forward on that.
Liz	**How do you perceive the overall usefulness of the tool?**
Dahlia	I suppose in this organizational case, it does identify on paper that this organization has difficulties with communication and collaboration and has the capacity and willingness to implement and roll out project changes, so it is useful in that regard. On a scale of 5 I would give it a 3.5 or let's say a 7. A 7 out of 10. It isn't necessarily a tool that I would want to tell myself that I'm going to complete it in an hour and a half. This may be a tool I may want to come back to a little bit at a time over the course a day so I have time to more absorb each section. I think it would be

	more effective if it wasn't approached as an hour and a half block. It should be approached as small blocks. Say between each section of the ranking, take a 5 minute break even if it's short so give people adequate time to think about it and see how your answers change.
Liz	**How do you perceive the amount of time needed to use the tool?**
Dahlia	It kind of became painstaking half way through. Especially though the ranking page. You feel like you put a fair amount of thought into it as you have the stamina. You can a lot of stamina to put the thought into the first 3 or 4 sections and then you start getting into section 5 or section 6 and you're wondering "when is this going to be over?" So I definitely see the tool as taking too long to want to use.
Liz	**If you used the tool for a future collaborative project, when during the project would you use it and how?**
Dahlia	I would honestly want to send that out to partners before or immediately after kickoff to help them identify things that need to get situated before the project really get stuck. So if you jump into a project and find maybe your N University collaborators are really terrible at something, I'd like to know that at the start of the project rather than half way through it.
Liz	**What recommendations would you offer an organization considering using the tool?**
Dahlia	To not take it in a 2 hour block. Give your manager a couple days to work on it and encourage them to work on it in 10 minute blocks over the course of a few days.
Liz	**What characteristics of an organization would they need to maximize their benefit out of using the tool? What is the ideal organization or person to complete this?**
Dahlia	Definitely a manager. Certainly someone in a coordinator type role. Probably the project manager on the collaboration.
Liz	**What would you say are the most important things you learned from using the tool today?**
Dahlia	I don't really know how to answer that. Because some of this stuff was incredibly hypothetical and some of it wasn't. They have some opportunities to improve their collaboration methods, their file sharing methods for example. That's a weakness that we've identified early on in the project which should be addressed before later on in the project. There needs to be more closely and well defined file sharing capabilities.

Esmeralda


Error:
Dimension 1 Step 1
Incomplete
Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Dimension 2 Step1
Dimension 2 Step 2
Dimension 2 Step 3
Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Dimension 4 Step1
Dimension 4 Step 2
Dimension 4 Step 3
Dimension 5 Step1
Dimension 5 Step 2
Dimension 5 Step 3
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Quit

Esmeralda was a non-native English speaker and Master's student. She could not provide a clear level of understanding of either absorptive capacity or collaborative innovation network aligning with the way either term is used within the tool. She had never used Simos' method.

The scenario that was developed for Esmeralda was based on her Master's thesis research project involving morph charts. In reality her project did not have any collaborators outside of Clemson, however one industry partner had been considered early within the research. This partner organization had not joined the project, however for the sake of the scenario Esmeralda was asked to imagine that they had. Esmeralda was concerned about her confidentiality when discussing this partner so she was told that she could refer to the company as "Company X" if she preferred. Esmeralda discussed that she was roughly 35% of the way into her project and that she was in the design of experiment phase. She noted that identifying the phase she was in was difficult as it was not how she naturally thought about her project. The research project had begun officially at the start of August 2018 and was expected to be complete January 2019.

Esmeralda was given the concise version of the tool. During the initial review of the tool, Esmeralda can be heard reading aloud from the sheet. Upon reaching the first mention of the acronym CIN within the introduction (8m 14s), she immediately asks what that the acronym means and just as quickly finds it defined on the sheet. She can be heard sounding somewhat exasperated trying to read everything aloud, so I chose to step in to remind her that she does not have to read everything at this stage. She asked if it was okay for her to choose for herself whether she read everything aloud or not and she was told she most

absolutely could. Esmeralda then reads a bit more before reaching the first mention of the acronym SME and asks (9m 0s) what this acronym means. As I knew it would be given to her following the script I chose not to answer her at this time, however a few seconds later she can be heard reading the definition on the sheet (9m 15s). She asks (10m 29s) whether acquisition means "owning something" or "making it yours" however I did not answer. This definition is loosely accurate. Assimilation she thought meant to "absorb into your own system" which is more accurate. She can be heard wondering (11m 21s) about the point of the tool saying that absorbing knowledge is what anyone should do, therefore she did not understand why there needed to be a figure for it. She can later be heard asking an unintelligible question (11m 48s) which I assumed was rhetorical and did not respond to. Further on (12m 36s) she asks "Who monitors these people? Are they supposed to just figure it out on their own?" to which I do not respond. This is not elaborated upon further at this time. She reads aloud some more and then after some seconds of silence and being unprompted to begin talking again she asks (14m 21s) whether she is supposed to be thinking aloud. I confirm that yes she is to be thinking aloud as feels most natural. She then explains that the think aloud process sometimes cannot be done because not all of her thoughts are well articulated. It is explained to her that the process of using think aloud is not meant to be invasive and that it is not required to articulate everything. Esmeralda correctly summarizes (15m 13s) that the tool can be used to track the values that people have and what matters to them and that within a CIN this can help make more informed choices. She asks (15m 56s) if I was eating something which she evidently found distracting. I believe I may have been absent mindedly chewing on my tongue at the time

so I made an effort to an effort to stop this habit for the duration of the test. Esmeralda then had trouble focusing back on the tool (16m 13s) and mentions that she is distracted. After finishing to read the introduction, Esmeralda asks (18m 10s) how many questions there are within the evaluation as well as something else unintelligible, both of which are denied. She is reminded of the prompt to simply navigate between sheets. Upon reaching the results page and noticing its length Esmeralda notes (19m 38s) that "this is going to require a manager and plenty of time if he does it right, which makes it wrong and which makes it useless." After this statement she apologizes and asks if this is my work or not. I encourage her to continue making comments and not to worry about my feelings, however I chose not to give her more information about who's work it was in hopes that she would continue her honesty. Towards the end of her initial review of the results page (21m 9s) she can be heard saying "Beautifully done, but I don't know what the goal is for here."

It was noticed that Esmeralda seemed somewhat stressed after having developed her scenario and completing her initial review of the tool. Before beginning the tasks, I chose to remind her (26m 49s) that she was perfectly allowed to take a pause at any point during the study if she wanted a coffee or to go get some water. At this point she decides to take a minute and a half break and leaves the room. When she gets back I return to the script and ask if she has any questions. Esmeralda responds by asking whether the objective of people or organizations using the tool is for them "to get something out of it." I let her know that I could not respond. She added that she thought the tool would help provide structure to collaboration but she felt that company's would not follow the structure. She asked me to verify something else shortly after to which I similarly responded that I could

not answer. Esmeralda appeared to be frustrated by my refusal to answer questions and asked "Well what kind of questions can you answer?" before trying to ask a question unrelated to the study to which I did respond to. She was then asked if we could continue with the tasks.

Esmeralda is prompted to read the introduction sheet (30m 11s) and is told that afterwards she will be asked to summarize it. She was quiet for 2 minutes while she reread the sheet and then gave her summary. Esmeralda makes a comprehensive summary of the tool focusing on the objectives of the tool, what the results show, and how the results would be used by an imagined organization. She is then asked to evaluate her workload for this task (34m 8s). Noticeably, despite seeming stressed leading up to the task, Esmeralda indicates very low levels of perceived workload in all categories including frustration. The highest of the workload measures was performance. At one point during Esmeralda's workload evaluation I chuckled to release tension which she found distracting. Although I had been making an effort to be as neutral as possible before this point, I made more of a conscious effort to not chuckle or make unnecessary noise for the rest of the study. Despite indicating an exceptionally low temporal demand, while evaluating workload she can also be heard saying (41m 33s) "My god, is it going to take us 5 hours for us to do this thing?" I assure her that I can spend whatever time is needed but she is reminded that we have only allotted 2 hours for the study. Notably Esmeralda took roughly 10 minutes to complete the workload evaluation (44m 19s). She asks for details about what I can and cannot disclose about participants to which I assure her I cannot discus anyone's specific results with anyone outside of those involved in the study and direct her to the IRB document.

Esmeralda then asks what she herself is allowed to disclose and I remind her that her participation in the study does not bind her in anyway. I add that I will explain at the end what aspects of the tool I would like to ask her to keep private out of professional courtesy.

Esmeralda now begins working on the context sheet narrating her thought process. She makes no additional comments during this part of the process.

Once complete, Esmeralda is prompted to begin the ranking sheet. After reading aloud some of the instructions she comments (55m 6s) that "Ok, I am getting tired talking." She is encouraged to continue narrating her thought process but that she does not need to read everything out loud. Esmeralda reads quietly for a bit and then comments (56m 41s) that "maybe I'm taking this too seriously" before starting to narrate her thought process as she begins thinking about the first dimension. She asks (57m 30s) again about how much time does she have and she is reminded of the 2 hour allotment but not told how much time has passed. She indicates (57m 43s) that it hurts her to talk a lot as she is getting over some sort of illness. I tell her that the study is not supposed to cause any level of discomfort and that if the think-aloud format is a problem that we can stop the study. She does not mention it further at this time and instead continues with the study. Later she asks about the meaning of something but what she was referring to was unclear. I indicated that I could not answer her question, but she was encouraged to continue asking questions. Esmeralda later comments (59m 24s) that "If you perfect this thing you are going to make a lot of money though. If it's perfected it could be a good concept." After reading a few of the practices she complains about the writing style (59m 48). When asked to elaborate she says "It's beautiful, it's kind of like the French language. Too curvy, too nice, too fancy. I love it.

Don't get me wrong, I love French. But what I'm trying to get at is sometimes if you don't want to go that deep with people. Not everyone is that deep. Many people that go that deep are problems." It is unclear whether the participant was familiar with the tool's connection with the French language or not but it can be assumed that she was. Her statements may suggest some bias towards the language used in the tool due to this perceived connection with French. Ultimately the problem she seems to identify with the practices is that they require a deep level of thought which she does not expect others to be able to do. Esmeralda goes on the suggest "If you really want good collaboration, good innovation, with multiple companies you just need two people who are chosen by their own managers who are allowed to just talk it out. You may think they are going to have so many misconceptions if they are chosen wrong, but how they are chosen right, that is the whole skill of the manager of the company. He knows what his company needs. If he is thinking about making a mistake he will ask me before making a mistake which is a lot to ask for I know." Esmeralda identifies that another obstacle she has with understanding the practices is that she is not the "managerial type" implying that the types of vocabulary used are unfamiliar due to being domain specific. When Esmeralda seems to be nearing the point where she was ready to begin assigning numerical ranks (1h 2m 42s), she reminds herself that the ranks must be consecutive but says that she does not understand what that means. After reading the practices for the second dimension (1h 3m 30s) she seems to indicate that she is finished with the sheet though she has not completed any part of the ranking process. She is reminded that the task was to complete the steps for each dimension to which she responds asking "The whole thing? Right now? The numbers and stuff?" I confirm this and

remind her that she can take a break at any point. She chooses to refer back to the instructions. After reading the "Confused? Need help? Click the nearest button for help troubleshooting" statement, she decides to click on validation button for the first dimension before completing any part of the dimension and is of course notified that **step one is incomplete.** This is the first and last time she will click any of these buttons before completing the entire sheet.

Esmeralda begins completing all nine dimensions using an imagined 10-point rating scale for step 1 with 10 being very important and 1 being not important. Not understanding the meaning of step 2 but seeing in the instructions that at least one pair must be given a unit of difference of 1, Esmeralda chooses to put 1 in all user input cells for step 2 throughout the sheet. Her responses for step 3 are either 5 or 10 which often aligns with the highest rated practice within each dimension this is not always the case. Upon reaching the fifth dimension she does notice one of the headers is still in French and asks whether I got the tool from France. I choose not to answer. She adds that "this does seem like a French thing though, it's just translated I think." A while later (1h 22m 20s) she requests a short break. She is reminded that she can pause or stop the test whenever she likes. When asked if she is giving up or just taking a break, Esmeralda indicates that she is just taking a small break though she never leaves the room and takes it as an opportunity to make some additional comments. She discusses that the tool seems important and well designed. She makes a self-deprecating comment about intelligence but adds that she likes to be particular and methodical with these sorts of assessments. She also notes that the tool relies upon intuition gained from experience. Immediately after making these comments she can be

heard reading additional practices and continuing the assessment (1h 23m 47s). Once she is done with all dimensions (1h 25m 15s) Esmeralda asks if she should click on the green button. Following the script, I notify her that she should complete the steps for all dimensions in hopes that she might try clicking one of the red buttons to check her work instead. She decides to click green button. I ask if she is done with the ranking sheet and she confirms.

At this point I intervene in hopes of salvaging part of Esmeralda's work. We save her workbook at this time. I tell her that we are going to go back and redo the first dimension, but that I will guide her through the process. I also tell her that we will simply do the evaluation part for this first dimension. I begin reexplaining how the process works, however is the process of doing so I accidently disconnected the charger from Esmeralda's computer causing it to shut off. During my explanation of the process, Esmeralda explains that "rank is kind of a general term. A rank can be like a score." She then explained an alternative way of describing the process as "You could have said it's a priority. Is it an A priority, B priority, C priority, D priority, E priority? If it's an A priority, call it 1. If it's a B priority call it 2. If it's a C priority call it 3. But tell us how big of a difference it there is. Between priority 1 and priority 2, major difference. Why? Because it's a difference of 3 instead of 1." She added that "So design lexicons are the words that we all use and we all think that we all know what they mean and we always find out that there's a different meaning." She then referred to the example figure as a "priority line." We then step by step completed the first dimension. Once step 1 was correct I allowed her to attempt step 2 on her own but she believed that the instructions told her that the differences between all

ranked pairs had to be 1 unit of difference. This was reexplained that only the closest pair had to be 1 unit of difference. I then attempted to draw an illustrative figure as I was struggling to communicate it effectively verbally. Emeralda patiently waits for me to finish explaining but then asks to quit the study as she is out of time.

Table 10-17. Esmeralda Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Esmeralda	So I'm looking at design fixation of people using morph charts. So everyone has internal design criteria of their own. Sometimes it's a good thing to have internal design criteria and sometimes its not and they each have their own utilities. So if I can figure out if someone has a design fixation. There's the fixation work that A did or design fixation which I'm hoping to do. I should be able to identify that information or make it available in some way so that who on earth knows how to use that design fixation information for improving the design process should be able to do so.
Liz	**Is this a collaborative project with any industry partners? Is this a funded project?**
Esmeralda	No, this is just a project for my thesis. And if Dr. S wants me to collaborate with somebody I'm happy to do so but as far as I know, until this point I really don't know of any partners.
Liz	**Are you on any other more collaborative projects? You're a grading assistant aren't you?**
Esmeralda	Yea, is that a collaborative project?
Liz	**So you're not also a research assistant?**
Esmeralda	No, I just do grad advising which you do to so you already know. So that's about it.
Liz	**So regarding the project you are working on underneath Dr. S, what phase in the project would you say that you are?**
Esmeralda	I would say that I am in the… I know I'm technically in the design of test and deployment phase and will get the results and do the analysis and write the thesis. But that's the whole process. I don't really think in terms of the step. I should probably. Sequence is certainly a better thing to do. It gives you less stress. There's always going to be offshoots of whatever you are doing that are completely unnecessary and useless probably…
Liz	**So would you say you're very early in the project or are you somewhere in the middle?**
Esmeralda	It's kind of hard to know. For example what you don't know you don't know. Based on what I know. Based on the way that things are. I would say I'm 35% into the project.
Liz	**So when did this project start?**
Esmeralda	It started somewhere in March 2018 … but it didn't have its own outline officially, it had a different outline until June or end of July or something. August 1st was when I was sure.

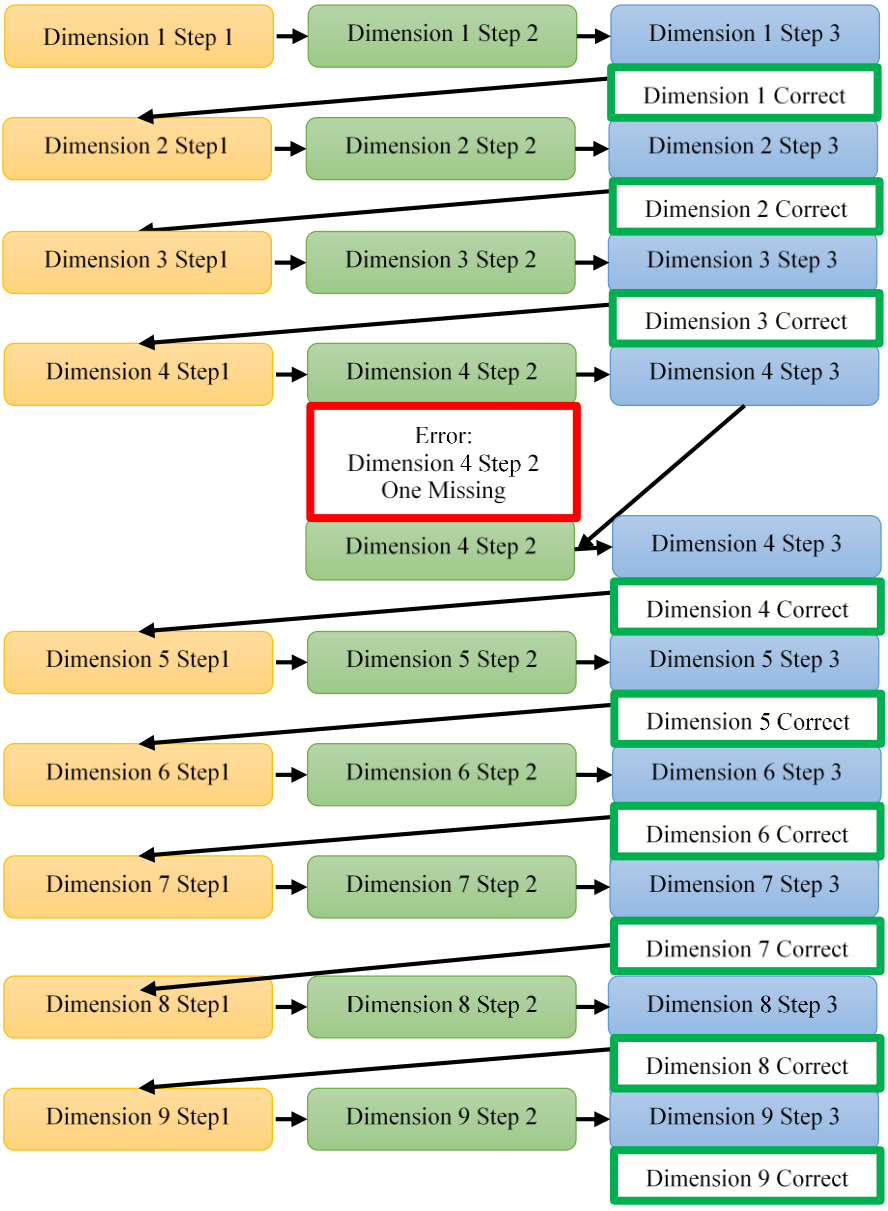
Liz	**Do you know what you're expected completion date would be for this project?**
Esmeralda	That's another you don't know what you don't know.
Liz	**Could you provide an estimate?**
Esmeralda	So up until now I was hoping for January 8th. This coming January. That is what I was hoping. But if things keep going the way they are that is going to be impossible or say near impossible. Near impossible if I was… other things I suppose.
Liz	**Do you think by the end of next semester?**
Esmeralda	So May, right?
Liz	**Yeah.**
Esmeralda	More than enough time. So I'm saying more than enough time because as long as the system doesn't… as long as the unnecessary burdens, it's basically my own weaknesses. So basically so long as…
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Esmeralda	Absorptive capacity of what? Just absorptive capacity? Based on the context there are so many examples in my brain but I can't narrow it down to one so I'm just going to say it's an amount that you can incorporate into something else without any saturation.
Liz	**What about the notion of a collaborative innovation network?**
Esmeralda	So that would be an amazing thing. I don't know what that is. It could be amazing if it is implemented in the way it is supposed to be implemented which it's not I think because it's… I do hope that the collaborative innovation networks are supposed to be the norm by now instead of being the exception.
Liz	**What do you see as its definition then?**
Esmeralda	The definition is basically not in the innovation or the network, it's basically in the systems you manage. How you manage creating something useful. Being able to manage them is something of a… I'm guessing it's a complicated task. And if you hurry it up you mess it up or if you slow it down you still mess it up. So I suppose it's super hard and I don't know if everyone's currently doing it. I'm happy with it.
Liz	**Have you ever used Simos' method?**
Esmeralda	What is that?
Liz	**That's my question.**
Esmeralda	Then no I have not.

Table 10-18. Esmeralda Scenario Development

Liz	**In this scenario, imagine that one of your research projects is the project being worked on. So for this scenario we are going to use your research under Dr. S, so this is the innovation project being worked on.**
Esmeralda	For my SME?
Liz	**Your SME, yes.**
Esmeralda	So my SME is doing research on morph charts and they are trying to figure out how to make their designers more productive. Let's say that's my case. Am I the owner or am I the designer or am I the guy who is going to use the results?
Liz	**That is up to your discretion but I think you'll be able to figure that out as we go along. So again this is your SME, you and everyone at Clemson University on your…**
Esmeralda	Who do you give this document when you go to your company?
Liz	**I can't tell you that.**
Esmeralda	Sorry.
Liz	**You're doing fine. These kinds of questions are good so stay in the habit of asking them. Unfortunately, I can't answer that one but I promise I will go back and answer whatever you're curious about at the end. So continue asking anyway, it will be very helpful for me. Let me try going back to my script. Everyone at Clemson on your research team including your advisor(s) are a part of your SME that you are representing. Any other industry partners which yours unfortunately doesn't have, so we may have to imagine an additional extra partner. This may be say, a partner university that you're collaborating with some of their researchers at this other university. So does that sound like something that could reasonably happen that you could imagine?**
Esmeralda	That did almost happen. But understandable.
Liz	**Can you describe what almost happened and we can alter it for the scenario so that it actually happened?**
Esmeralda	I think I have confidentiality, right?
Liz	**You don't have to give me anything specific.**
Esmeralda	So a certain project was coming under the certain professor that I am working for and it didn't go through because I wasn't at the right spot in my project at that moment or otherwise the collaboration would have happened.
Liz	**Is this still the morph chart project or is this a separate project?**
Esmeralda	It's almost the same. The experiments are nearly the same. As long as I have one I can do the others. The only problem is that I can't… I'm struggling to be honest, with a lot of things.
Liz	**So was this an industry?**
Esmeralda	It was an industry, yes. That I cannot disclose.
Liz	**That's fine, you don't need to. So for the sake of being able to talk about it out loud we are going to say this is company X. So company X is going to be your collaborative… will be another SME. So your SME is Clemson University being you and your advisers and your research team, company X will be a part of your collaboration innovation network or your CIN. Keep that in your head, you may have to use your imagination. That's fine. So.**

	Everyone at Clemson on your research team including your advisor(s) are a part of your SME that you are representing. Any other industry partners – namely company X – which are involved in your project would be considered other members of your Collaborative Innovation Network.

Fantine


Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Dimension 1 Correct
Dimension 2 Step1
Dimension 2 Step 2
Dimension 2 Step 3
Dimension 2 Correct
Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Dimension 3 Correct
Dimension 4 Step1
Dimension 4 Step 2
Dimension 4 Step 3
Error:
Dimension 4 Step 2
One Missing
Dimension 4 Step 2
Dimension 4 Step 3
Dimension 4 Correct
Dimension 5 Step1
Dimension 5 Step 2
Dimension 5 Step 3
Dimension 5 Correct
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Dimension 6 Correct
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Dimension 9 Correct

Fantine was a native English speaker and Master's student. She was unfamiliar with the terms absorptive capacity and collaborative innovation network. She had never used Simos' method before.

Fantine's scenario was based on an industry research project she was working on. This is noticeably the same project as Baptistine had used for scenario. The project involved assessing distractions within an automotive manufacturing environment and then analyzing their effects on mental workload. Fantine identified that CUICAR was not currently involved in the project but would be in the future. The automotive company occasionally gives some feedback but is otherwise not a very active collaborator on the project. Fantine's project had started in August and she felt that her team was currently in the design of experiment phase. She believed her project would last for about a year ending next August. Fantine identified 2 current research collaborators, including Baptistine, as well as two past researchers who had involved in a previous phase of the project. Her partners on the project were the automotive manufacturer and CUICAR.

Fantine was given the concise version of the tool. Her only question during her initial review of the tool was whether or not the tool would calculate as we went which I did not provide an answer to.

Fantine noted (8m 10s) during her review of the introduction that she found the definitions succinct. She also asked whether there was a learning effect expected from using as the tool states that it is expected to take less time on future evaluations. During her summary she discussed that the tool would assess the strengths and weaknesses of a

firm's willingness and capacity to process external knowledge to "more surgically improve your collaboration."

Fantine then began completing the context sheet seeming to correctly use the scale narrating her thought process as she went.

She then began the ranking sheet. After reading the instructions she asks for clarification (19m 56s) that 1 is the highest rank and that higher number represent less importance, though I do not confirm this for her. She noticed (20m 26s) that 4 practices had since appeared underneath the first-dimension headers which had not been there during her initial review of the tool and correctly interpreted this as meaning that these would be the ones she would be ranking. Upon reaching step 2 (22m 25s) she indicates that she is putting a 1 between ranks 1 and 2 because they are the closest illustrating that she correctly understands step 2. She indicates (23m 15s) that the reason she chose to put 6 for step 3 was due to the fact that there were 6 units between the highest and lowest rank, however she indicated that there were actually 8 units between the highest rank 1 and lowest rank 4. It is unclear how 6 was decided but she is able to **validate the dimension**.

Upon reaching dimension 2 where she only had 1 practice, Fantine felt it odd that she still had to rank it. She used the button the **check that this was correct** and quickly moved on to the next dimension.

Fantine then reached dimension 3 where she had 8 practices. She noted (25m 42s) that she wished these were grouped together. She commented that she thought the words "personal objectives" might be a typo and was supposed to be "personnel objectives"

within context of the other practices. She was able to validate the dimension using the corresponding button.

Fantine similarly completed dimension 4, however when clicked on the validation button the first time (32m 32s) she **had not identified the smallest unit of difference for step 2 as 1** for this dimension. She thinks about this for a few seconds (32m 43s) and then realizes her mistake. She briefly goes back to dimension 3 to verify that she did it correct though she does not change anything. For dimension 4, Fantine had given the 3 practices shown a rank of either 1 or 2. As a result only one pair of ranks was shown for step 2 which she felt were not close to each other, so she naturally wanted to put a value higher than 1. After realizing her mistake after reading the error message, she explained that she understood now that step 3 was the proportion of importance whereas step 2 was asking for the difference. She corrected herself for steps 2 and 3 and then revalidated and found that **she was correct.**

Fantine then proceeds to correctly complete dimensions 5 through 9, **validating with the button as she goes**. She does notice the header still in French within the 5th dimension. She realizes (37m 26s) that she has previously not been considering the phases specifically as she completed her ranking and asks if she can refer back to the introduction sheet. She is allowed to do so and spends a few seconds reviewing this sheet. She thinks aloud about her project a bit and then states that she is not going to change the way she is ranking the practices as she still did not know exactly what the phases were or how they related back to her project. She later discusses (39m 30s) that she had at one point consulted a psychology professor and other faculty at Clemson University who may be considered as

"another resource for our organization." She comments that she is actually considering the phase while thinking about her rankings now and is conflicted whether she should change her earlier work (40m 57s). Towards the end (50m 46s) she adds that she feels like she had a bit of learning bias and that "I think now that I have gotten through the entire 9 sections, I feel like knowing my thoughts about 8 and 9 and what phase it was in, that if I started over at the top I think these numbers might be different."

Upon beginning the evaluation sheet she notes (52m 21s) that if she had not accidently scrolled up she would not have realized she was not at the top of the page when she was first directed to this sheet due to the frozen headers at the top. She later comments (53m 26s) that she likes the metrics capacity and willingness a lot since she recognizes them from her past study of change management, particularly related to the principles of ADKAR which suggest that for permanent changes to be made awareness, desire, knowledge, ability and reinforcement are needed. Fantine's strategy for completing the evaluation was to complete all of the capacity column for the first phase and then go back and do the willingness column for that phase. She commented (1h 2m 53s) that it was good that the scale was used an even number because if it had been a scale of 5 she would have put a neutral 3 for almost everything. When finished with her evaluation she did decide to click the green button again (1h 10m 43s) though it had no effect.

Fantine was finally asked to interpret her results. Notably Fantine was on a Mac laptop which meant that her radar chart formatted slightly irregularly from how it was originally formatted on a Windows PC which caused her some confusion. She was able to use her scores to identify dimensions which were strengths or weaknesses. Fantine revisited the

introduction sheet hoping to learn more about what these dimensions were but could not find a satisfactory amount of information. She was not able to draw the connection between the context sheet and the relevancy percentages. When analyzing the maturity grids, she notably looked at the distribution of practices within this grid. She felt that grids which had practices located close together would be easy ones to improve in, even if these were all in the green region. Fantine was more inclined to begin finding action items from her practice strengths rather than her practice weaknesses as she generally was not willing to change those, nor did she find them important. She was confused by the meaning of importances and how it correlated with the maturity grid, however she was able to interpret it correctly by the end of her analysis. Her practice strengths she identified as "quick wins," believing that if these were practices which her organization was not already doing they would be quick and easy to implement. She added that her strengths were as a result of internal networks within her research team and the fact that they had many resources for getting external knowledge. She identified an immature practice as a weakness but discussed that she felt it was not actually a weakness as it was not important. She decided that supply chain knowledge was a more realistic weakness and was able to identify the cause. She added that this practice was primarily done by one individual on the research team which was why the rest of the team was weak in it. Fantine discussed that the way things are currently actually works pretty well and that even this lack of supply chain knowledge within most of the team was not really a problem for them. She did think that she believed she could benefit from better understanding the expectations of the project, specifically more about client wishes.

At this point she completed her workload assessment where she identified an increase in mental demand and temporal demand. Frustration was noticeably higher than it had been after the introduction.

During Fantine's debrief she explained that she did not feel the tool was that difficult to figure out, however did mention that she felt she only fully understood the ranking process towards the end. She identified interpreting the results as the most difficult, specifically correlating the importance to the capacity and willingness. When asked about the easiest part of the tool, Fantine mentioned that the instructions were well laid out and succinct. She also identified the ranking part as easy once you learn it. She felt the results were the greatest effort challenge. She added that she did not feel the tool was useful in its current form, but that if the results could be translated a different way it would be more useful. Fantine suggested that the results could include top strengths, top weaknesses, quick wins, or items which may need outside resources it would be more useful. Fantine ultimately believed that the tool identified maturity and importance of practices but not necessarily weaknesses or strengths in those practices. She felt that if she were to use the tool again that she could do it a lot faster, but that an hour was a pretty long time when you are exerting effort in the interpretation. Fantine believed that the tool was most useful early within the project but after roles and some boundaries within the project had been defined. She recommended that if an organization wanted to use the tool, they should have an expert help them interpret the results. She felt that organizations would only benefit from using the tool if they had and willingness and openness to change management and self evaluation. The most valuable thing she felt she learned pertained more to the kinds of

questions I had asked during the debriefing. She noted that she thought more about perception of ease of use and usefulness were greatly hinging on the output. Fantine added that despite the ranking being complex (which she had previously identified as one of the easier parts of using the tool) that the tool would seem more useful if the output was something easier to interpret, even if that meant compromising on how "surgical" the process was.

Table 10-19. Fantine Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Fantine	So I'm on a project with company B where we're assessing mental workload in assembly. And then I'm on a line-balancing project with company S. And then my thesis research.
Liz	**Which of these, preferably of the first two projects you mentioned, would you say you are more familiar with?**
Fantine	The company B one.
Liz	**At what phase in this project would you say you are?**
Fantine	We're in the design of experiment phase, we're getting past the pilot study phase and are in data collection.
Liz	**Is this the one at CUICAR?**
Fantine	It will be. But the design of experiment part we're going to do here with the hope that you would do it at the vehicle assembly center.
Liz	**Is that the moving platform thing?**
Fantine	Yes.
Liz	**When did this project start and do you know an expected completion date?**
Fantine	I started on it this August. Probably next August probably.
Liz	**Who all is involved in the project?**
Fantine	Me, M, A, and before that D and H.
Liz	**Is this a collaborative project with company B? Are they involved in the project a lot?**
Fantine	No, we get their feedback on things. We just wrote a report on which physiological measures we're going to assess the amount of workload.
Liz	**Is this for them though?**
Fantine	Yeah, it's for them. The goal is to assess distractions in their actual environment. So when I started on it they went and gathered distractions that they observed.
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Fantine	No.
Liz	**What about the notion of a collaborative innovation network?**
Fantine	No.
Liz	**Were you at my presentation the other week?**
Fantine	Yes. That's the only exposure I've had to it so I don't know if that counted.

Liz	**Have you ever used Simos' method?**
Fantine	No.

Table 10-20. Fantine Scenario Development

Liz	**In this scenario, imagine that one of your research projects – namely your project with company B – is the project being worked on. Everyone at Clemson University on your research team, including your advisers, is a part of the SME you are representing – including other collaborators. Any other industry partners which are involved in your project – company B – would be considered other members of your collaborative innovation network. Do you have any other collaborators other than the ones at Clemson and the ones at company B?**
Fantine	Dr. M is a stakeholder, I don't know if I'd call him a partner.
Liz	**If you would like, you can consider CUICAR as a separate SME as well. So to reiterate, everyone at Clemson on your research team including your advisers is a part of your SME that you are representing and any other industry partners including ICAR as well as company B involved in your project would be considered other members of your collaborative innovation network.**

Table 10-21. Fantine Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Fantine	So I'm looking at the radar chart first because it catches my eye. So there's the white line but there's no legend entry for that so I guess that makes sense that's the outside baseline. But then there's those colors behind it so I'm having trouble making sense of the orange and the blue lines because the white lines… it seems like a symmetrical shape but… it's not and it's confusing. So for preparing acquisition, the white line goes all the way out to the blue line but for learning assimilation the white line is a far distance away from the edge of the green shape so it looks like the blue for learning assimilation I think is further out from the center than the blue line from preparation acquisition but it's not readily obvious. But despite all that, I think it says that we're strong in learning assimilation and we're strong on all counts and achievement assimilation and that we're relatively weak on capacity and willingness within the preparation phases particularly preparation assimilation and preparation application. We scored the worst it seems for both capacity and willingness within preparation application and weirdly enough we scored really high on willing on learning application but the capacity was very low so that seems to indicate something that we just need some training on. Relevancy to context… Now looking at the table besides the radar chart too, the relevancy to context is really all I'm looking at not the capacity or willingness yet, 100% for, now I still don't really know what learning assimilation is. May I navigate to the introduction tab one more time?
Liz	**Sure.**
Fantine	Navigating to the introduction tab again just to make sure that I understand. So I'm wondering what learning assimilation is because it's relevant to our context but there's nothing, unless I'm missing something, there's nothing that on this introduction tab which helps me really understand more of what that is. When looking at the table my first thought is what is the highest score on got on these and what's the lowest score. So when I saw 100% for learning assimilation, I generally think that means we know how to share information well and we know how to input information but I don't really know. And then the lowest score we got was 20% for achievement application and preparation assimilation. The interesting thing to note about the achievement application is that we got the relevance to context as 100% maturity on it for willingness and 81% for capacity, so I'm kind of confused there and am wondering how that's calculated. Not because I doubt it but… but because I'm curious.
Liz	**Next analyze the other figures underneath for each dimension. Describe their general meaning and explain how you would interpret these. Walk me through how you would interpret some of these.**
Fantine	So now I'm scrolling down and I'm reading the intstructions… distribution practices of the thematic – I don't really know what this means – according to your organization's maturity scores. So I'm looking at preparation of acquisition of external knowledge and I see the extreme value which is 1.9 which is in this green capacity bucket and it seems we are the most willing and capable to learn 1.9, to implement 1.9 so I look over here and I see that it's 25% important so maybe there's some disparity between how important I said it was and our capability and

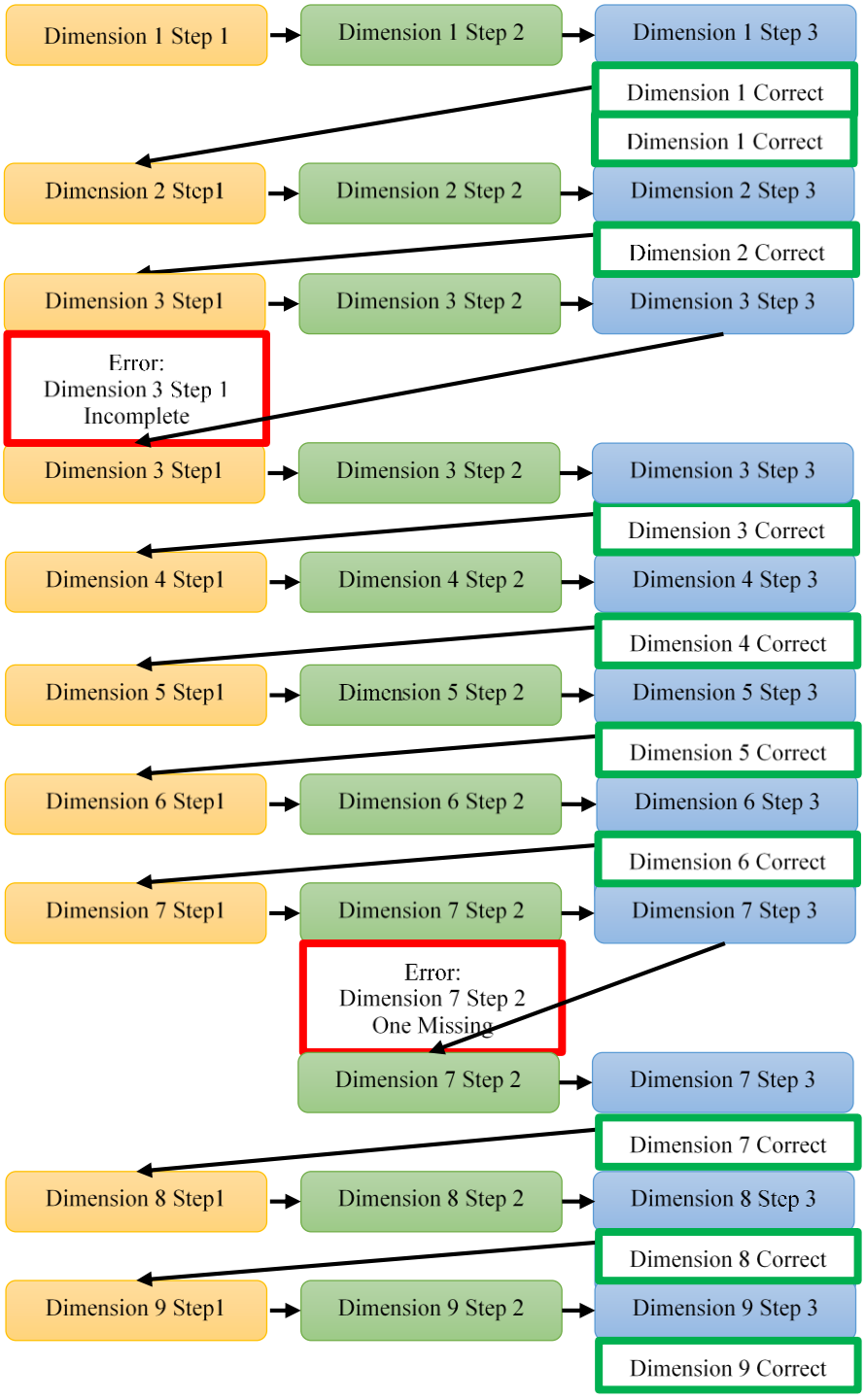
	willingness. So I understand this colored graph but coupled with the importance it's confusing me. I'm not sure what to make of that. It's clear that this is what capacity and willingness says but I'm not sure how to interpret it coupled with the importance. So I'm looking at preparation application and I'm looking at the most extreme one 3.1 because they both have 1 for willingness and capacity. But it's also only 2% important to our organization. So that one makes sense. I don't think that shows that we have a need for that because it, again, is not important to us which is why we don't have the willingness and don't have the capacity. So I'm kind of struggling to identify strengths and weaknesses from that perspective which is something that the introduction said it would help with. So I'm still a little confused. So achievement phase, the second two, they are both grouped heavily in the green quadrant which is 4 and 4. So for dimensions 4 and 5 I see that they are spaced differently so I'm taking that to mean that I scored them differently. But ultimately relatively high willingness, relatively high capacity. This is where I think having done it in terms of the phase would have helped because up here I said the conference thing was important and here it's 9% important so I'm a little confused about that. So I understand the results but I don't know how they would be helpful. But it does reaffirm that we allocate resources well and that we like to use those resources to promote some of our findings. On 7, the distribution is all over the place. Interestingly I don't think I have any practices for any dimension in the upper right quadrant. So I guess I didn't give any a 1 or a 2 for willingness and a 3 or 4 for capacity is what that shows me so that's weird to me. So there's some relationship there. So for 7, the importances being so scattered is interesting to me. So maybe we're spread too thin on that or maybe we need to focus our efforts more, I'm not sure. It's also odd that there's 9 different things for 7 but only 1 for 2. I just don't know why. So looking at 8, I see they are all grouped together and the importance is scattered so these must be quick ones to improve. Versus if I see a big distribution I don't even want to tackle this as is the case with 7. So with 9, I see an outlier in 9.6 where it seems to have gotten a 1 for willingness and a 1 for capacity but I don't know, it could be a 2. And it's 12% important. So we're not willing and we're not capable and I did say it wasn't very important so. So it being in the red quadrant I'm thinking we need to work on that but then I see the importance at 12 and then I'm thinking maybe not. So I'm overall a little confused about these results but my major takeaway is that when I see a tight grouping, like in 4, 5, 6, 8, I'm thinking those could be quick wins because we have the capacity and wiliness to implement those activities if we haven't already. Maybe the importance has some correlation to whether we are already doing them or not.
Liz	**Can you identify an area of strength?**
Fantine	Yeah, so the tight group on 8, learning from assimilation of external knowledge. It's a quick win in the sense that if we weren't already doing it we could easily implement it quickly but also I get the feeling that that's also a strength of ours so maybe not?
Liz	**What do you think is the cause of this strength?**
Fantine	So let's take 4, achieving acquisition of external knowledge. So that seems like a strength because it's all in the green quadrant. We're willing to do this, we have good tools for doing that and a well connected network of professors and our boss per se is very connected. We have financial resources where we can go to

	conferences and things like that. So I'd say it's because our tools and infrastructure for finding out what's out there.
Liz	**Can you identify an area of weakness?**
Fantine	So when I see the red I think that that's a weakness but it's not necessarily an area of weakness because it just means we're not capable and willing to do something because if it is, for example 7.3, it has low scores for willingness and capability but also has 2% importance so I don't know if that's a weakness or if it's just not important to us.
Liz	**Can you identify an area of weakness?**
Fantine	I would say that "collects supply chain knowledge" would be, or maybe if I thought about it a little bit harder. We are pretty confident about the suppliers of the heart rate monitors that we buy from this vendor are going to work for us based on their rating so maybe that's underestimating how much supply chain knowledge we have but knowing that the heart rate monitor gives us reliable data which gives us reliable insights gives us reliable things to say about distractions in the work environment. That's a hard sell for me to say how integral that supply chain knowledge is to our final product. That might be a weakness if we get some bad equipment but having access to the product reviews I don't think that's really supply chain knowledge but I guess it qualifies.
Liz	**Can you take a guess at what the cause of that weakness might be?**
Fantine	Lack of education. It's just not something we cover, supply chain logistics. We blindly follow product reviews which may be a problem with society.
Liz	**What action would you recommend that your organization take to improve in areas where it may be weak?**
Fantine	So looking at another purported weakness. Looking at 7.5 which ended up in the red box with low capacity and low willingness but it's 20% important, but we could improve on something there. I don't think this one is a weakness across the board I just think it's something that's traditionally in the hands of one person – in this case Dr. S – so our organization on a whole is weak on it because not everybody knows how that works and maybe they should but it's not necessarily a weakness that we really should make everyone more involved in because really the way we do it now does pretty well.
Liz	**What action would you recommend that you specifically take to improve in areas where you or your organization may be weak?**
Fantine	I think learning that process a little more related to 7.5. And learning more about the expectation of the project.

Table 10-22. Fantine Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Fantine	How to use the tool wasn't difficult necessarily, after the first couple rounds of ranking and all that, it made more sense towards the end. Interpreting was very difficult.
Liz	**Which parts of the tool were the most difficult and why?**
Fantine	The results. Trying to decipher what was a strength and what was a weakness. Correlating the importance to the capacity and willingness, that was very hard.
Liz	**Which parts were the easiest and why?**
Fantine	The instructions were laid out pretty well I thought. As succinctly as they could be. With the ranking and the units. So with the ranking part, once you learn that I thought it was easy but there was a learning curve.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Fantine	The only part where the effort was a challenge was the results and figuring out what this means.
Liz	**How do you perceive the overall usefulness of the tool?**
Fantine	I think that if there was another way of translating what is on the results tab to "top strengths/top weaknesses/quickest wins/may need outside resources for" a breakdown like that, I think it would be more useful. But as it stands now, unless you really broke it down for me it's not useful as far as understanding strengths and weaknesses.
Liz	**How do you perceive the amount of time needed to use the tool?**
Fantine	I definitely could do it faster if I did it again in another context. But it was an hour which is a pretty long time especially if you're exerting effort in the interpretation.
Liz	**If you used the tool during a future collaborative project, when during the project would you use it and how?**
Fantine	I think it would be best early on but not necessarily early for the sake of being early. It'd be best early on once you've identified roles of who is doing what. Because we're still in the process of learning what the roles are. I think once you have greater boundaries.
Liz	**What recommendations do you have to an organization considering using the tool?**
Fantine	You may need some expert help in interpreting the results section.
Liz	**What characteristics of an organization would they need to maximize their benefit out of using the tool?**
Fantine	A willingness to change and an openness to change management. Firms that don't want to change won't. And a willingness to self-evaluate.
Liz	**What would you say are the most important things you learned from using the tool today?**
Fantine	I've thought more about perceived ease of use and perceived usefulness and part of that hinging on the output. So even though the ranking was more complex as long as the output is something I can understand then it would have made it feel more useful. Even if it wasn't as surgical as I'm sure this is if I knew how to interpret it.

Juliette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Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Error:
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Incomplete
Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Dimension 3 Correct
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Dimension 4 Step 2
Dimension 4 Step 3
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Dimension 5 Step 3
Dimension 5 Correct
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Dimension 6 Correct
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Error:
Dimension 7 Step 2
One Missing
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Dimension 9 Correct

Juliette was a native English speaker and PhD student. She was not familiar with absorptive capacity or collaboration innovation networks and had never used Simos' method.

Juliette scenario was based on her PhD research. Unfortunately, her project was not collaborative, so she was asked to imagine that external researcher from a different university with a different experience set was brought in to help. Juliette indicated that this would be easy enough to imagine. In her scenario she would represent her Clemson research team which involved her and a Mechanical Engineering faculty advising on the project who was partnered with this other university composed of an imaginary PhD researcher and their adviser.

Juliette was given the non-concise version of the tool. She did a quick skim of every sheet during her initial review of the tool and noted at the end (5m 39s) that she did not understand anything yet.

Juliette was prompted to review the introduction sheet. Early on (11m 51s) she can be heard commenting on finding the figure misleading saying "The acquisition under preparation is the exact same as acquisition under achievement. All three of them are exactly the same. They ought to be very different but…" She later notes that she disagrees with the definition of capacity, claiming instead that it refers to "achievement" or "mastery" (13m 41s).

Next Juliette completed the context sheet, seeming to correctly use the scale and narrating her thought process as she went. She noted (15m 56s) that she was unsure about the meaning of the word "concurrent" and ultimately decided to ignore it. Later (18m 11s)

she notes that she is the only one working on her project. I intervene slightly to remind her about her collaborators. She also remembers at this point that her organization is referring to Clemson University composed of her and her faculty adviser. She then makes an effort to specifically mention and include her imaginary collaborator as applicable while completing the rest of the context sheet.

Juliette then began the ranking sheet. She found (20m 46s) a minor typo within the work "certain." She later commented (21m 30s) that "this ranking system seems really, I could just assign a numerical importance and get the same results. But I don't know, maybe there's a reason." For the first dimension, Juliette only had one relevant practice and was able to conclude that it had to be ranked 1 and is then able to **validate the thematic which she does twice.**

She moves onto the 2nd dimension which similarly only has one relevant practice. She able to complete this without any problems and **validates her response using the button.**

Juliette quickly completes dimension 3 not noticing to bottom four practices with the dimension. When she clicks the button (24m 0s) she is notified that **step 1 is incomplete** and quickly realizes what she missed. She then finds another minor typo in practice 3.14 where an "of" is missing. Juliette comments (26m 18s) that "it's hard to give these different things a rank." She later adds (29m 11s) that the fact that there is not enough concrete detail makes considering relative importance difficult. She continues adjusting her responses, using same rank for some practices, and clicks the button again **finding that she is now correct.**

Between dimensions 3 and 4, she notes (30m 31s) that "external data sources are useful, but they're never quite as helpful as data you can generate yourself, especially for research." Towards the end of dimension 4 she comments (31m 11s) that she does not have any confidence in what values the ranking process calculates and does not feel that they would be a useful model of importance. She validates using the button and finds **herself correct for this dimension.**

Upon reaching dimension 5, Juliette comments (33m 57s) that "I feel like these are the second half of sentences and I'm missing the first half." She completes dimensions 5 and 6 with no further problems and **validates that both are correct.**

After completing dimension 7 she receives a notification (36m 16s) that **at least one pair for step 2 must be equal to 1 unit**. She very quickly adjusts and revalidates (36m 24s), finding her **work correct.**

She completes dimensions 8 and 9 with no issues and similarly **validates both are correct using their respective buttons**. During this Juliette comments (38m 5s) that these practices seem more applicable to projects bigger and more complex that she viewed her own project. She reiterates from a prior statement that she finds it hard to separate the usefulness of these practices (38m 35s), in particular 8.1, 8.2, 8.4, and 8.5 which Juliette decides to keep all at the same rank. She notes that she feels these are all facets of the same activity.

Juliette then began the evaluation sheet. She complains that she is having difficulty seeing many questions at once (43m 10s) with the way the scales are frozen at the top.

She then reaches the results sheet where she struggles to interpret her maturity scores due to lack of understanding of what each phase and dimension truly means. Upon analyzing the maturity charts, Juliette felt that the tool did not adequately consider importance as many of her practices located in the red were immature because she did not need them or find them important. Juliette was able to discuss her strengths and what made these strengths, however when asked to identify weaknesses she focused primarily on the fact that she felt the tool was highlighting unimportant things. She did not seem to notice the importance values or pair them with her analysis of the maturity grids in any specific way. In her scenario, she had identified that she saw herself as being responsible for 95% of her organization and thus was not able to identify ways her organization could improve that were different from what she herself thought she could improve.

Juliette stated that she found the tool pretty easy to figure out, however was not sure if she had done the ranking process right and later identified this as being the most difficult part for her. She complained that she did not see a clear definition of what "right" was and wanted more context into how things were being calculated and what her responses meant to make better judgments. Juliette felt that evaluation and context were the easiest due to them being straight forward. She felt that the effort required to use the tool was moderate. She noted that she did not trust the results as she was not familiar with how her responses were being used to calculate her results. Juliette also believed that the tool had inherent importance values behind the scenes being used which she did not trust. Juliette commented that the tool would be more applicable in a more complicated business project management context. She could see herself using the tool to give herself negotiating power

with collaborators as justification for why she felt they should improve in certain areas, however she did not believe that the tool was going to tell her something she did not already know. She felt that the tool took a reasonable amount of time and would be worth it for more complex situations to help make big decisions. Juliette believed that the tool was most useful about a quarter of the way into a project, after the mission statement had been formalized but before a full plan had been developed. She noted that the tool required a good understanding of who was involved in the project and their skill sets to get useful results. Her recommendation to organizations considering to use the tool was ultimately only use it if you have a need to. Juliette commented that she felt the tool could be useful to organizations with independent team divisions to create an interface. She added that simple organizations do not really have a need for the tool but if they had a certain level of complicatedness they could benefit. She did not feel that she learned anything but noted that she does not trust a some research due to its reliance on abstract theories.

Table 10-23. Juliette Initial Interview Responses

Juliette	What research projects am I currently working on? Describe them briefly. I am doing a research project to determine the causes of size effects in lattice structure materials. So lattice structure materials can be something like a honeycomb and the apparent elastic properties of that and how many unit cells are within that honeycomb. I'm trying to make that connection more clear.
Liz	**So is this a project that you are working on with other people?**
Juliette	I am not.
Liz	**Is it industry funded?**
Juliette	It is not.
Liz	**Who is your adviser on the project?**
Juliette	Dr. T. I am near completion on the project. The project started when I came to Clemson 4 or 5 years ago.
Liz	**When are you estimating that you'll be done with the project.**
Juliette	Spring.
Liz	**Are you familiar with the concept of Absorptive -**
Juliette	No.
Liz	**Were you present for my presentation?**
Juliette	No.
Liz	**What about the notion of a Collaborative Innovation Network?**
Juliette	No.
Liz	**Have you ever used Simos' method?**
Juliette	No.

Table 10-24. Juliette Scenario Development

Liz	**In this scenario, imagine that one of your research projects is the project being worked on. So your project isn't very collaborative because it's something that you're working on independently.**
Juliette	It could be.
Liz	**How so?**
Juliette	If I had collaborators to collaborate with, what I'm doing couldn't be done with multiple people. It would not be very efficient but I can pretend that that's what we're doing.
Liz	**Is this a project that originated from a different project? Or might turn into a different project later on?**
Juliette	The project has kind of mutated and I kind of expect it to be abandoned when I'm gone. But that has everything to do with both the people involved and the content.
Liz	**Even if they aren't heavily involved who would you say these other collaborators are?**
Juliette	95% me. And 5% Dr. T. So without me it's going to fall apart
Liz	**Have you worked on any more collaborative projects? Ones working with industry ideally or other universities.**
Juliette	Not within academia, when I had an industry job I would have to do collaborative stuff all the time.
Liz	**For the sake of being somewhat consistent between participants, let's imagine that your current research project that you're working on that you are familiar with and almost completed with, is a collaborative project. We'll say that there is another researcher involved at another university with a knowledge set that you may not be familiar with. If you could hire somebody, what would they be like?**
Juliette	That's easy to imagine.
Liz	**So let's rationalize them. Who is this imaginary collaborator?**
Juliette	Let's say Bob.
Liz	**Where does Bob work?**
Juliette	The University of A.
Liz	**Ok, so you are working on this project under Dr. T. We'll say Bob is a similar researcher to yourself and is also a PhD student in an area of research you are not necessarily familiar with. So your SME is both you and Dr. T. Your partner organization would consist of Bob and his adviser. So in this scenario imagine that one of your research projects is the project being worked on – this one that we've just created. Everyone at Clemson on your research team including your advisers are part of your SME that you are representing. Any other industry partners involved in your project – namely this other university – would be considered other members of your collaboration innovation network.**

Table 10-25. Juliette Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Juliette	There's a bunch of numbers, I don't know what they mean. This kind of goes back to how I don't know how the three areas are different from each other because the descriptions of them are the same in the introduction. Preparation, achievement, and one-way learning. Those seem different but why are the components copy pasted? Those two seem contradictory. Evidently, I am well prepared to prepare. I am slightly less prepared to achieve. And not particularly well prepared to apply what I've learned. My capacity and willingness seem to go together pretty well. There's some relevance to context over here, and I have no idea what that means. I feel like there's something I could learn from this but I just don't… it just seems like a bunch of numbers.
Liz	**Next, analyze the other figures underneath for each dimension/thematic. Describe their general meaning. How would you interpret these?**
Juliette	So the little colored box chart. I am three out of four capable and willing to do 1.3 which is explore relevant market knowledge. I have a low capacity and almost 0 willingness 2.11 and 2.12 which are ensuring that we know what the roles are and then contractualizing those roles. Do I have to go through all of these?
Liz	**Not necessarily. If you could just walk me through your interpretation of one or a couple of them.**
Juliette	I could interpret them but I don't know if I could make any sort of action plan based off of them.
Liz	**Please identify an area of strength.**
Juliette	So exploring and acquiring knowledge I believe came up nicely in the results.
Liz	**To reiterate the question, can you identify an area of strength?**
Juliette	So this says I'm willing and capable of figuring out my project objectives aligned with the strategic orientation of my organization and figuring out what I need on this project to get me where I'm going.
Liz	**What do you think is the cause of this strength?**
Juliette	At the moment I have pretty clear goals. I know what my research direction is and what could support that.
Liz	**Similarly, can you identify an area of weakness?**
Juliette	Ensuring that everyone agrees on what research should get done. And putting that in a contractual manner is, according to this, is an area of weakness that does assume, this document, this method is assuming that certain things are important and they may not be important to me. So I'm not sure if it counts as an area of weakness or not.
Liz	**What do you think is the cause of this weakness?**
Juliette	I don't think it's important and I haven't invested in building my capacity to do that.
Liz	**What action would you recommend that your organization take to improve in an area where it may be weak?**
Juliette	So for the previous weakness I identified, I would not recommend that any action be done, no sense spending resources or time on that. For other areas of weakness, if we were to actually apply this research I would have no idea how to do that and I would

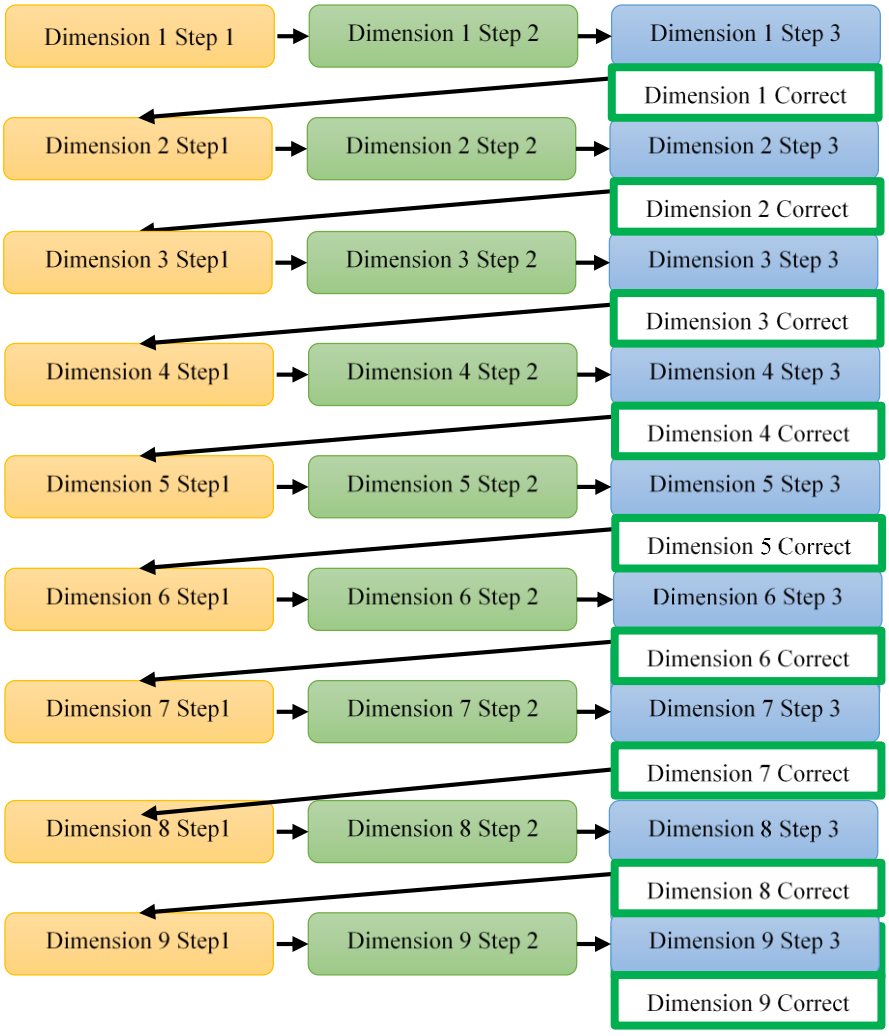
	have to develop contacts with industry, possibly bring in outside help, and I would have to learn a lot more about the actual application process.
Liz	**What action would you recommend that you specifically take to improve in an area where you or your organization may be weak? You are notably a large part of your organization.**
Juliette	I could develop industry contacts, talk to people who actually know how to apply this.

Table 10-26. Juliette Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Juliette	Pretty easy to figure out what I was supposed to do. I'm not entirely sure I did that second page right, the ranking of the different importances. I did not see a clear definition of what "right" was. And I didn't have enough context to know what my answers mean to make good judgments.
Liz	**Which parts of the tool were the most difficult and why?**
Juliette	The ranking for sure.
Liz	**Why is that?**
Juliette	I didn't have any good reference was what a correct answer was. I was missing a lot of context.
Liz	**What parts were the easiest and why?**
Juliette	The evaluation was pretty straight forward. The context was also pretty straight forward. I felt like I knew what I was doing for those parts.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Juliette	Medium I guess? I got it done in however much time this took. I'm not particularly stressed out but a little unsure if I did it right, but not too much effort.
Liz	**How do you perceive the overall usefulness of the tool?**
Juliette	I would not trust the results. It's not quite a black box. I can tell what's going on kind of. There seems to be some implicit values that are behind the tool, certain things are important. And some of the results were you are not very mature or capable in a certain area but I haven't developed maturity there because I haven't needed to. If I were to use this in a more complicated context, in an actual business project management context, what might happen is I might use it as an excuse to do what I was going to do anyway and use it to justify telling collaborators to learn about how fluid mechanics works or how to better design power tools. I would use this tool to tell myself that and then say "Hey Bob, the tool told me to tell you…"
Liz	**How do you perceive the amount of time needed to use the tool?**
Juliette	It's a very reasonable amount of time to help make the big decisions if this is used for something sufficiently complicated requiring that that decision should be a slow one.
Liz	**If you used the tool for a future collaborative project, when during the project would you use it and how?**
Juliette	If you use it at the very beginning I think that it's going to fail because you haven't thought anything through at all. I think it would be most useful about a quarter of the way through or after you have a general plan. After you have a mission statement but before you have a real plan. You have to come into this with an inventory of who the people are and what they're relative skills are or it's not really going to tell you anything more useful.
Liz	**What recommendations would you offer an organization considering using this tool?**
Juliette	So assuming an organization is even in a position where they might need it… it seems like my recommendation is going to be either use or don't use it.
Liz	**What characteristics of an organization would they need in order to maximize their benefit out of using the tool?**

Juliette	It seems like it's design for a fairly specific situation where you have multiple components of a larger organization that are somewhat independent. So let's say company, I don't know how company T works but I can take some guesses. So they have a division responsible for manufacturing, another for designing tools, those two sub-organizations are independent and have to work to interface. So that organization would have to be defined and managed. If something is very simple, if an organization or group of organizations is very simple, and there's somebody who knows everything going on, you don't really need this tool. But after a certain threshold of complicatedness, you need this tool.
Liz	**What would you say are the most important things you learned from using the tool today?**
Juliette	I'm just going to go ahead and talk crap about design in general. A lot of design research I don't really believe in. It's just abstract theories trying to say that "this is true" so I'm not really sure I learned anything.

Léopoldine



Léopoldine was a non-native English speaker and PhD student. She was not familiar with absorptive capacity or collaboration innovation networks and had never used Simos' method.

Léopoldine chose to focus on her current research project involving heat assisted single point incremental forming processes. In reality this project did not have an industrial partner involved in the project, however some companies had been pitched the research at

the beginning of the project. One particular company was discussed which had been interested but had too strict of requirements for the project which could not be met by the university. In Léopoldine's scenario, she was asked to imagine her project as if this company had decided to work with her team. She added that her project had started in Fall of 2016 and would continue until summer of 2019. She felt that she was pretty close to completion of her project.

Léopoldine was given the non-concise version of the tool. She was not familiar with absorptive capacity or collaboration innovation networks and had never used Simos' method.

Léopoldine's first question during her initial review of the tool (3m 41 s) was what the acronym "SME" was. As it would be included in the script later on, I did intervene and choose to tell her what it was. Léopoldine later asked (4m 49s) whether external knowledge referred to knowledge still within the CIN or completely outside of the CIN, to which I did not provide an answer. She did attempt to format part of the evaluation sheet to be better viewed but the sheet protections did not allow it. Upon viewing the radar chart on the results page, she noted (12m 7s) that not a lot of people choose to represent scores this way.

While reading through the introduction, Léopoldine noted (19m 7s) that although the tool is for self-evaluation, she felt it would be most useful to see how other collaborators completed the evaluation.

Léopoldine correctly used the scale on the context sheet, narrating her thought process as she went.

Next, Léopoldine is tasked with completing the ranking process. She can be heard reading through the instructions and eventually comments (25m 22s) that 6 was a high value on the last sheet whereas on the ranking sheet, 1 was a high value. Upon reading step 2, she comments (26m 18s) "I thought you already took care of it when you assign ranks consecutively" illustrating that she does not yet understand the meaning of step 2. She then adds after reading the directions for step 3 that "this is confusing" before processing it a bit more and indicating that she felt she understood. While reading through the summary and example part of the instructions she asks (28m 35s) "Since it's consecutive it's always going to be 1, 1, 1, right? Because if I put 1 and then no 2 and then directly 3, that would violate this rule where you say they have to be consecutive." I did not answer her question.

She then quickly completes steps 1 through 3 for all dimensions never making any triggerable errors and **validating using the red buttons as she goes.** Léopoldine noticeably puts 1 for all of her inputs into step 2 until she gets to dimension 7. For dimension 7 she had 10 relevant practices and does comment (39m 3s) that "this is a handful. There's too many options. And trying to rank them takes some effort to think about which are more important." She otherwise completes dimension 7 with no further problems. Léopoldine also does not use same rank until she reaches dimension 8. Her values for step 3 do not appear to be connected to the numerical value of the lowest rank for that dimension which suggests that she is properly interpreting this step.

At the end of the ranking, Léopoldine clicks the calculation button and waits. She is automatically navigated to the evaluation sheet. Her screen shows her the frozen header, however the bottom half of the screen is completely blank as she had previously scrolled

down too far to see anything. I initially choose not to intervene to see if she could figure this out for herself (46m 44s). She notes that she does not have to click the green button again and reads the scale on the right. She then asks (47m 35s) "So I should go to the results now? Where do I put the scores in?" I ask whether she would like to indicate that she is finished which she confirms (48m 0s), so I proceed to the next task to see if she would figure it out upon seeing her lack of results. While reading the prompt for this task, she clicks again on the green validation button on the evaluation sheet to see what would happen. Nothing changed so she does decide to move on the results page as prompted. I read (48m 42s) her the task prompt for a second time. At this point skims the instructions and then tries to edit her scores which the sheet's protections disallow her from doing. She realizes (49m 15s) that she "already has a score. I'm not sure where you put your scores for capacity and willingness." I continue to not intervene, though she makes it clear that she realizes that she has missed something but makes an effort to look at the radar chart and find meaning. I reiterate the results prompt. Despite having scores of zero for every dimension she says "It looks like I'm not doing good in these categories. Achievement acquisition and preparation application but on most of the others for example, the preparation for acquisition and achievement application… am I answering your question?" At this point (50m 42s) I choose to intervene. I redirect her to the evaluation sheet again and show her how to scroll back up to the top. I reread the evaluation prompt and allow her to proceed (51m 11s) like normal. Léopoldine then completes the evaluation process without issue but does decide to click the ready to calculate button for a third time when she is complete. She notes while it is calculating "I guess I didn't need to do that."

Léopoldine was then asked to analyze her results. She understood that the relevance to context percentages could be interpreted as how important that dimension was to her project which she generally agreed with. When analyzing the maturity grids and practices listed by importance, she focused on those practices in the red and yellow noting high and low capacity levels as she went. She never specifically discussed the importance percentages of these practices. She identified that an area of strength was on the openness within her organization to share ideas and felt that her weaknesses were cause primarily due to lack of experience. She felt that training members of her organization by sending them to partner organization strong in her organization's weaknesses could be a good improvement tactic. Léopoldine may have given simplified strengths and weaknesses during this interview as she thought she would have to complete the plan of action sheet.

Léopoldine felt that the process was not very hard but did later note that she felt there was a bit of a learning curve. She commented that "initially it's going to be difficult but it's easy in the end." She felt that her primary obstacle was the GUI itself. She referred back to how to evaluation sheet had not shown practices initially and how she felt the button usage only being required on one page was confusing. She also felt that dimensions with many practices were very difficult to rank but that fewer practices were much easier to rank. She questioned the usefulness. Léopoldine was apprehensive about how the person completing the evaluation would be determined which she felt greatly effected how trustworthy she would find their responses. She discussed that organizations wanting to use this tool must be willing to collaborate and could benefit best from this collaboration when they are lacking certain expertise and want to break into a new field. The most

important thing that felt that she learned pertained to new criteria she had not considered before.

Table 10-27. Léopoldine Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Léopoldine	I'm working on assimilation of the heat assisted single point incremental forming process. So my goal is to see if I can develop an assimilation model that can predict the temperature and deformation of a polymer undergoing a process so that I can save experts time and money.
Liz	**Is this a collaborative project with other people?**
Léopoldine	No, it's just me.
Liz	**Who is your adviser?**
Léopoldine	Dr. M.
Liz	**Are you funded by any external sources?**
Léopoldine	No.
Liz	**Ideally I was hoping you'd have a project collaborative with industry. Have you had any other more collaborative projects within the past couple years?**
Léopoldine	No, we did try to pitch this idea to a couple of companies, but it didn't happen.
Liz	**So let's imagine that one or two of these potential companies agreed. Can you describe who these companies are that you are working with?**
Léopoldine	So for example, company E has some thermal forming planned. So the other day somebody came from company E, and we told them this could be used for prototyping but their requirements were really… they needed a machine with a very high output. Not something like what we have in the lab.
Liz	**So for the sake of the study, think of company E as a collaborator, and I'll go into more detail on this later. For this project, what phase would you say that you are?**
Léopoldine	I would say that we're pretty close to completion. We're waiting on final results. So we can validate our model.
Liz	**When did the project start and when would be the expected completion date?**
Léopoldine	So we started Fall of 2016 and I should be finishing it before the beginning of summer 2019.
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Léopoldine	I am not.
Liz	**What about the notion of a collaborative innovation network?**
Léopoldine	No.
Liz	**Have you ever used Simos' method?**
Léopoldine	No.

Table 10-28. Léopoldine Scenario Development

Liz	**In this scenario, imagine that one of your research projects is the project being worked on. So in your case you are going to imagine that that is your current research. So within this project you are going to have yourselves as one SME, one organization, which is you and Dr. M and whoever else here is collaborating with you in the lab. Outside of that will be company E which may be collaborating with you on parts of the project. If you can, try to imagine what company E's involvement might be if they were collaborating with you. You can flesh some of that out when you do the context sheet. So you're working together on an innovation project. In this scenario, imagine that one of your research projects is the project being worked on. Everyone at Clemson on your research team including your advisors are a part of your SME that you are representing. Any other industry partners which are involved in your project – namely company E – would be considered other members of your Collaborative Innovation Network.**

Table 10-29. Léopoldine Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Léopoldine	So it looks to me that my organization has a good sense for learning. We're ready to learn. And we're also good at implementing some achievements and contributions but I guess we need to learn how to prepare to contribute to the network. And then relevance to context, so it looks like for us, learning is the most important thing because it's 100% and 90% which makes sense because we're an academic organization.
Liz	**Next, analyze the figures underneath for each thematic. Describe their general meaning and how you would interpret these.**
Léopoldine	So I'm definitely not in the bottom 25% of organizations who aren't capable or willing. So we're definitely willing to do a lot of things though we may not necessarily have the capacity to those things. Especially this 1.3. We don't have the means to explore market knowledge. Other than that I think we're good when it comes to participating in scientific events or using some data sources, then assimilation, again good. Actively involves the client so we're willing and we have the capacity to communicate with the client continuously. 3.9, we do not currently have the capacity to develop a business model but we're willing to do that. Then I'm looking at 3.1, there seems like there's some reluctance to do that. 3.14, we're not very open to changing what we do. Number 4, everything is exemplary. We're all for talking between organizations. We are dedicated to the project so if need be we are willing to dedicate the human resources though we don't have the capacity. But we do want the knowledge to go out so that's why we promote the created innovated. 7.3 is in the red zone, collects supply chain knowledge. So according to us we feel it has no value which is totally the right thing. These two, 7.2 and 7.10, I guess we should apply more capacity here. We're ready to do that but we just don't currently have the capacity. And some of these are in the green area which I guess means we're ready in these areas to improve ourselves. And over here we're low on the willingness level so I suppose there's some apprehension there. I guess the more relevant point is that we're open to assimilating knowledge. 9.7, not really sure how to do that one.
Liz	**Can you identify an area of strength?**
Léopoldine	We are ready to learn.
Liz	**What do you think is the cause of this strength?**
Léopoldine	I guess there is more emphasis on talking and sharing whatever knowledge you have. So there's openness. We're always ready to share ideas.
Liz	**Can you identify an area of weakness?**
Léopoldine	I think we do not have the expertise necessary to acquire some things, like say the market knowledge.
Liz	**What do you think is the cause of that weakness?**
Léopoldine	We just don't have the expertise.
Liz	**What action would you recommend that your organization take to improve in areas where it may be weak?**
Léopoldine	So we should definitely collaborate more with our partners on these issues. Maybe we can send people from our organization to our collaborators to train

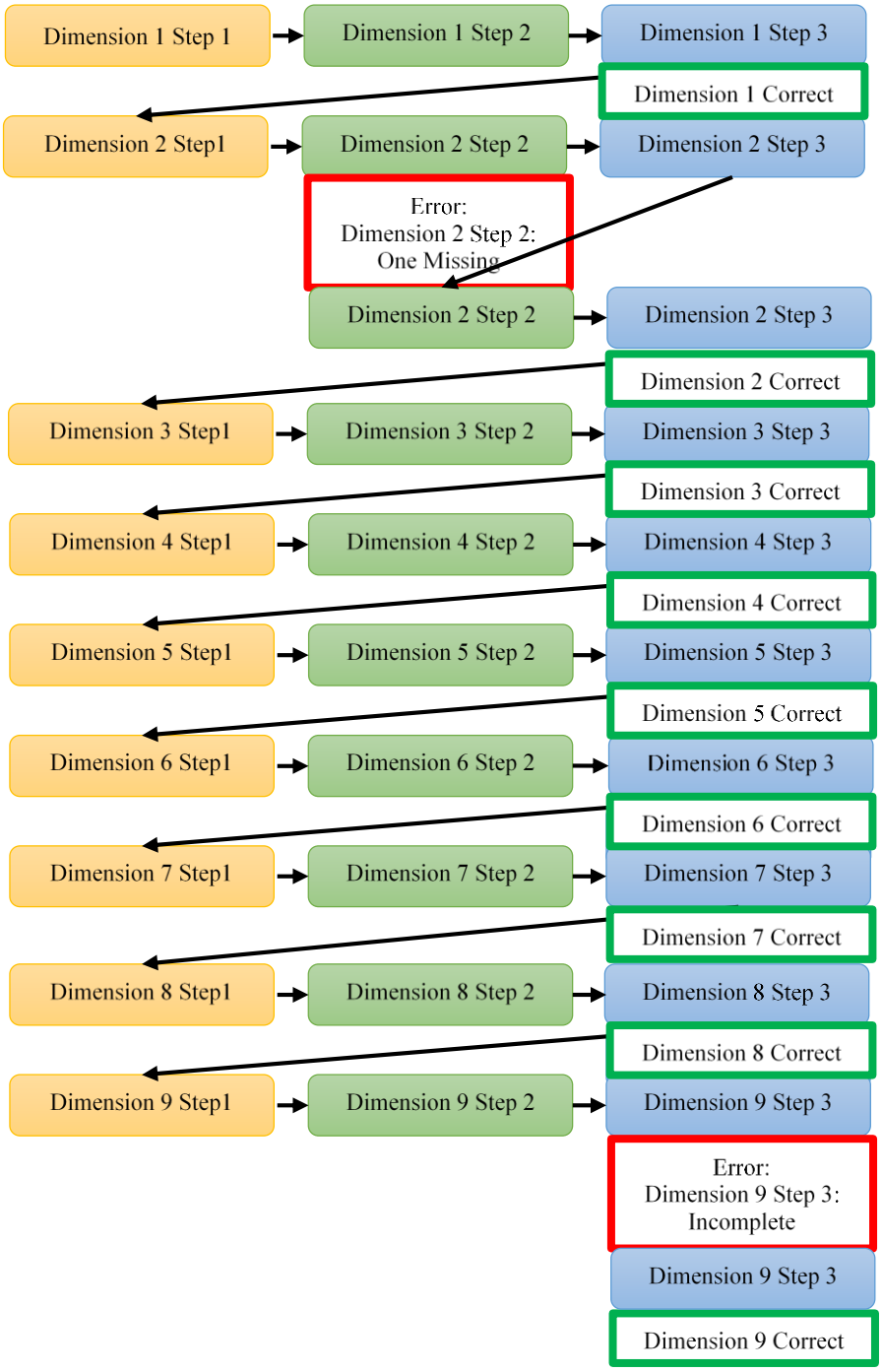
	them on the things we are lacking. And I guess we could use to this to identify which of our collaborators would be good for that.
Liz	**What actions would you recommend that you specifically take to improve in areas where you or your organization may be weak?**
Léopoldine	Undertake training.

Table 10-30. Léopoldine Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Léopoldine	Assigning the score wasn't. It sounds complicated but when it comes down to the questions it's not so bad.
Liz	**What parts of the tool of the tool were the most difficult and why?**
Léopoldine	I guess the GUI. Some of the things didn't appear and you've only got to press buttons on one page and not the others so that was confusing. Some questions had a lot more choices so ranking them or distinguishing between them took more time. So I guess they're not always equal.
Liz	**Which parts were the easiest and why?**
Léopoldine	The ones related to collaborating and sharing ideas and questions like that and in general questions with a limited number of questions.
Liz	**Can you identify a more specific part of the tool?**
Léopoldine	The preparation.
Liz	**How do you perceive the amount of effort to use the tool?**
Léopoldine	I think there's going to be a learning curve. So initially it's going to be difficult but it's easy in the end. Mediocre I guess.
Liz	**How do you perceive the overall usefulness of the tool?**
Léopoldine	I have two apprehensions. First, how do you make sure someone fits their responses? How do you know their responses are trustworthy? And second, how do you decide if this collaborator is good or bad and if it will work out or not? The tool seems pretty robust, looking at it, but I'm not sure if it hits on these two ideas.
Liz	**How do you perceive the amount of time needed to use the tool?**
Léopoldine	So this is a onetime thing that takes one and half hours, it's good enough. It justifies itself.
Liz	**If you used the tool on a future collaborative project, when during the project would you use it and how?**
Léopoldine	So I guess early on a new project, we want to make sure we're on the same page and if we're not we want to find which areas are going to be problematic. So for example if my company is not ready to communicate with the other and so on, so before the beginning of the project we'd like to do a feasibility study or compatibility study, I guess that's where we'd use this tool.
Liz	**What recommendations would you offer an organization considering using this tool?**
Léopoldine	I would say, take it multiple times. Not just once. There's subjective questions in there and the scores would depend on who does it. So there should be a way to select the people properly. And I think it would come with experience. Maybe they would use it for 6 months with their partners and see if that works out.
Liz	**What kinds of characteristics of an organization would they need in order to maximize their benefit out of using this tool? What is the ideal organization?**
Léopoldine	Definitely an organization that is willing to collaborate. So let's say an organization lacks certain expertise but they want to break into a new field, so at that time they would definitely need to collaborate.
Liz	**What would you say are the most important things that you learned while using the tool today?**

Léopoldine	There were some criteria which I had never considered before. So now I know learning has such a big importance within collaboration. So maybe there were some areas which were not clear to me that are so important to collaboration.

Magnon


Dimension 1 Step 1
Dimension 1 Step 2
Dimension 1 Step 3
Dimension 1 Correct
Dimension 2 Step1
Dimension 2 Step 2
Dimension 2 Step 3
Error:
Dimension 2 Step 2:
One Missing
Dimension 2 Step 2
Dimension 2 Step 3
Dimension 2 Correct
Dimension 3 Step1
Dimension 3 Step 2
Dimension 3 Step 3
Dimension 3 Correct
Dimension 4 Step1
Dimension 4 Step 2
Dimension 4 Step 3
Dimension 4 Correct
Dimension 5 Step1
Dimension 5 Step 2
Dimension 5 Step 3
Dimension 5 Correct
Dimension 6 Step1
Dimension 6 Step 2
Dimension 6 Step 3
Dimension 6 Correct
Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Error:
Dimension 9 Step 3:
Incomplete
Dimension 9 Step 3
Dimension 9 Correct

Magnon was a native English speaker and Master's student. She was not familiar with absorptive capacity or collaboration innovation networks and had never used Simos' method.

Magnon's scenario was based on her Master's research project which had begun during the summer of 2017 and would end by the end of November 2018. As she only had about a month or two left on her project, she was close to the end noting that she was at the design documentation phase. Magnon's project involved developing a measurement device was a company which had two primary participants on the project working with Magnon and her faculty adviser within the Mechanical Engineering department.

Magnon was given the non-concise version of the tool. During her initial review of the tool she can be heard commenting (2m 57s) that the length is reasonable enough to read being about two pages. Upon reaching the plan of action sheet (4m 57s) Magnon notes that she is expecting this sheet to auto-populate and complains about the formatting here.

Magnon is then prompted to read the introduction for understanding and told that she will need to provide a summary when she is finished. Early on (8m 32s) she comments that "there are a lot of five-dollar words, it takes a while to read." She adds that she has never heard of ACAP, or CIN, or SME, though all of these had been at least briefly covered in the script. Magnon elaborates that it would be clearer to write each of these out, particularly considering that these would be the first-time users would be coming across these. Later (10m 2s) she can be heard figuring out the CIN was collaborative innovation network. After reviewing the figure illustrating the ACAP dimensions she comments (11m 51s) that within each phase are the same metrics which she seems apprehensive of. She also did not

understand the meaning of "achievement" as she interpreted this term as being either you were successful, or you were not. Magnon comments that the tool does not seem that hard but that it is written at a very difficult level. When reading "This tool is recommended for use before the start of the SME's contribution to the CIN to identify its strengths and weaknesses" (13m 37s), Magnon originally interpreted "its" as referring to the tool itself rather than the individual representing their organization. She later notes (15m 29s) after reading the text underneath "self-evaluation" that she does not understand how it is self-evaluation if you are supposed to be representing your entire SME. Notably Magnon comments that "The box that says rank of importance actually makes sense." Towards the end she complains (19m 26s) that "I'm reading all this stuff but I still don't really understand the point." When asked if she had any final comments prior to provide a summary she recommended that all acronyms be replaced with their full terms and flip the order of how things are presented specifically leading with the objectives of the tool and how they are valuable. The summary she then provided focused who would use the tool, but stated that she did not understand how or why this tool would be used.

Magnon then completed a workload assessment for the task. She stated at the beginning that "I felt like it was actually pretty difficult and this is probably partially the industrial engineer in me. I get aggravated when things are more confusing than it needs to be. And I know there are plenty of Mechanical Engineers who just say 'well if you give it some time' but you shouldn't have to." On her assessment she indicated high levels of mental demand, frustration, and temporal demand.

Magnon then began working on the context sheet and early-on realized that the scale did not include a neutral value. Based on her commentary she does appear to correctly interpret the scale. Upon reaching the statements related to her partner organization, she asked (32m 12s) whether her partner was supposed to be the company that she was collaborating with outside of Clemson. I chose not to intervene at this point, however she was able to assess that yes, partner organizations was referring to her outside collaborator.

She was then prompted to begin the ranking sheet. Magnon likened completing the sheet to "filling out an I 9 form" (33m 42s). She proceeded to read the instructions silently before moving on the first dimension. She commented (36m 43s) that "it's kind of strange that there's all these gaps" referring to the white spaces between practices. She completes the first dimension with other problems and **validates her work using the red button** when she is finished.

She then moves on to dimension 2 where only 2 practices are shown. She completed the dimension and then validated using the red button but triggered an error (41m 29s) that she **had not defined at least one pair within step 2 as 1 unit of difference**. She immediately understood what change was needed and quickly adjusts her responses accordingly. She revalidates using the button and **finds herself to be correct**.

She then proceeds to **correctly complete dimensions 3 through 8** using the red buttons to validate. Upon reaching practice 3.3 which refers to the "human resources form your organization," Magnon notes (42m 7s) that this could be interpreted two ways: (1) the manpower of the organization or (2) its human resources representatives. She chose to interpret it as manpower. She then adds (42m 44s) that it becomes difficult to rank the

practices when there are a lot of them, most likely due to the 12 practices within dimension 3. Magnon then states that since her scenario was hypothetical she is going to "cheat" and not give a whole lot of thought to her responses here. At this point I prompted her to narrate her thought process so I could gauge whether she was thinking at all about the questions. She implied that she was planning on assigning them randomly and asked whether this would be a problem. I told her that she should do "as she naturally would do." I wanted her to put at least some level of thought into her responses or else I would need to ask her to give up, however if she felt inclined to respond in a way that made it easier for her to rationalize the ranking that was perfectly acceptable. She joked that she would naturally want to speed through it, but indicated that she would continue considering them. She can then be heard processing what ranks she wanted to give for this dimension. She comments (45m 9s) that "truthfully, about 4 of these I care about and everything else is kind of arbitrary because they aren't relevant." Magnon notably does not choose to use same rank for these arbitrary practices and will actually never use same rank within any dimension. During dimension 5 (49m 26s), Magnon is able to locate the header still in French. Much later (53m 1s) during dimension 7, she states that two practices are the same in her mind but still separates their rank.

Within the last seconds of the ranking process, she gets an error (55m 55s) about step 2 in dimension 9 not having at least one pair having 1 unit of difference which she quickly remedies and revalidates. Magnon's responses throughout the sheet show that she fully understood step 2, indicating at least 1 pair as having a difference of 1 unit while not

exclusively relying upon 1 unit of difference for all pairs. She does choose to click the green button at the end of the sheet.

Magnon then began working on the evaluation sheet. After completing a few of the practices she complained (57m 23s) that she wished she could make the frozen header go away. She notably put relatively high values for most practices so very little stood out from her results.

She was then asked to interpret these results. She was able to conclude that her organization was generally willing and capable on most things which she thought was primarily because she felt she had the resources to do all of those practices if desired. Magnon did identify that her organization was weak in preparation acquisition but was not able to – or more likely not motivated to – determine which practices were involved in to produce this. She reiterated multiple times that she did not find the tool very useful for an individual to complete as it does not tell you anything new. However, she did add that she felt it would be more appropriate for teams of at least 5 people or simply larger organizations to communicate objectives, values, and levels of agreement when working on a project. She felt that for very small teams, like hers, a quick conversation with her team mates would be more beneficial than spending the time needed to use the tool. Although previously stating she was not sure what specific areas she needed to improve, she did later state that "where we're weak, we don't need to be strong" referencing the maturity grids. It is unsure if she ever felt the need to specifically consider the importance based on her ranking.

Magnon found the tool complex, despite having seemed to have been able to figure it out at a high level rather quickly. She felt that the layout of the tool contributed to this and hinted at the level of the language used. She comments that "I could have done all this without the introduction and probably would have been less confused." Despite not getting what she viewed as useful results, she did note that she felt the results was the easiest in her mind. Magnon felt that an average person would have trouble using the tool as it requires a lot of cognitive demand. She felt that the tool would be most useful within diverse teams to communicate needs and values within the project. She did feel the amount of time required was not justified by the value of the results. Magnon thought the tool would be best used near to beginning of the project to keep collaborative organizations on the same page regarding their project priorities. She recommended that organizations simply start at the ranking sheet, though she most likely meant to skip reading the introduction. Despite not getting useful results, she felt that the tool had a wide variety of applications within industry. Magnon noted that there were a lot of goals and objectives for designing a project that she had not really considered, though she felt that was not directly relevant to her current project, particularly since she was so close to the end.

Table 10-31. Magnon Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Magnon	Research for my Master's?
Liz	**A research project of some sort.**
Magnon	I am building a device for company E which crawls into overlapping boards to detect measurements.
Liz	**Is this a project that you're working on with any other industries?**
Magnon	Just company E.
Liz	**At what phase in the project would you say you're at?**
Magnon	Still in the design documentation phase.
Liz	**Do you know when the project started and when it will roughly end?**
Magnon	The ideation started in the summer of 2017 and it better be finished by the end of November.
Liz	**Who are all collaborators on the project besides you and company E?**
Magnon	Specifically it's me, Dr. M and two guys from company E.
Liz	**Are you familiar with the concept of absorptive capacity?**
Magnon	No.
Liz	**How about the notion of a collaborative innovation network?**
Magnon	I assume people working together.
Liz	**Have you ever used Simos' method?**
Magnon	I have not.

Table 10-32. Magnon Scenario Development

Liz	**In this scenario, imagine that one of your research projects is the project being worked on. So in your particular case, your Clemson team will be the SME that you are representing whereas company E will be one of your collaborators or partner organizations.**
Magnon	I would have thought it would be the opposite of that.
Liz	**Are you working as a part of Clemson or as a part of company E?**
Magnon	I'm working as a part of Clemson.
Liz	**For the sake of this study, the research lab is considered an SME. To reiterate, everyone at Clemson that is a part of your research team including your advisers are a part of the SME that you are representing. Any other industry partners that you're involved in – namely company E – your project would be considered other members of your collaborative innovation network.**

Table 10-33. Magnon Results Interpretation

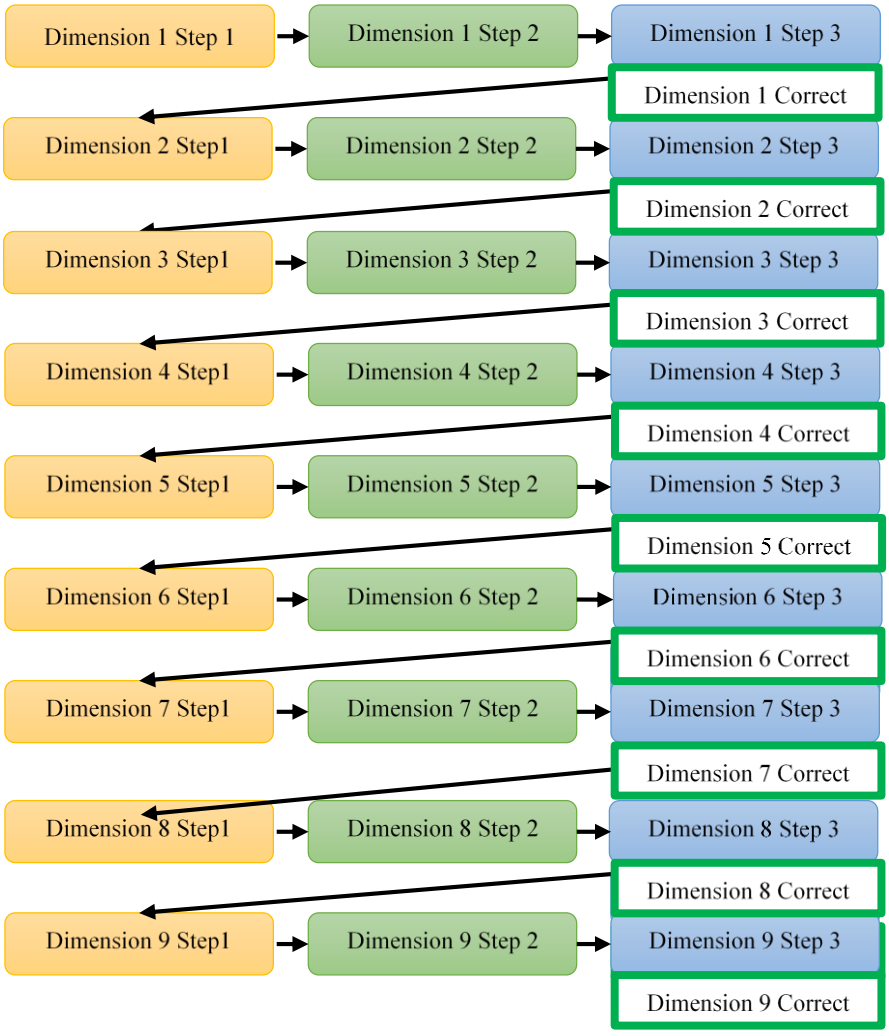
Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Magnon	So it looks like we've got the resources that we need primarily. For things that are and are not relevant to our work. I'm fine with that, I don't really have more on these numbers.
Liz	**Next, analyze the other figures underneath for each dimension. Describe their general meaning and explain how you would interpret these.**
Magnon	So I like the color coding. It makes it clear to me you to be in the green. So 1.9 is the first one I'm going to look at because it stands out as not so willing and not very capable. Well, if you're not willing but you're not capable, if you're not capable but you're not willing maybe it's okay. Ah, I don't really care about that. To me my big concern would be if you had a situation where you were very willing but you didn't have the capacity so if you were somewhere in this range in the lower left. Truthfully what I'm seeing is that we're willing and able on everything.
Liz	**Can you identify an area of strength?**
Magnon	Looking back at the top, preparation assimilation, we're willing and very able. The strength would be that we're very able. If we're not willing that's up to us.
Liz	**What do you think is the cause of this strength?**
Magnon	We have the resources to do it.
Liz	**Can you identify an area of weakness?**
Magnon	Preparation acquisition I suppose. It looks like we are less capable than we are willing which is not a good position to be in.
Liz	**What do you think is the cause of this weakness?**
Magnon	I don't know. I'm not sure which questions contributed to that.
Liz	**What action would you recommend that your organization take to improve in an area where it may be weak?**
Magnon	I don't know. I still don't fully understand what I'm looking at to be honest. I don't really understand the purpose or what it's supposed to show somebody. I mean this it's says here's what you're good at and bad at or are you interested in this, yes or no. Here's whether you're interested in it. Do you have all the resources to do all these things? Do you care about doing those things? Well here's what you care about and you do or do not have the resources to do it which to me isn't necessarily providing new knowledge. Maybe it helps people identify weak points. Maybe it's something where if you had 10 or 15 different people from a functional organization take this you could here's where everyone thinks that your weaknesses are and figures out what actions are value added and value lost, are you all in agreement on this? If not, why? How do you want to talk through this to achieve a common goal? But for as 1 person, it's asking what you are good at, what do you care about being good at, ok, here's what you're good at and what you care about being good at. So I'm not seeing a lot of new knowledge.
Liz	**What action would you recommend that you take to improve in areas where you or your organization may be weak?**
Magnon	Fortunately, what I'm seeing her is anywhere where we're weak we don't need to be strong. But that is because we're pretty much at the end of our design process. We've pretty much already explored our areas of weakness by this point.

Table 10-34. Magnon Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Magnon	I thought it was pretty complex. I thought it was unnecessarily complex. It wasn't hard tool to use it was just the way things were laid out was bizarre.
Liz	**Which parts of the tool were the most difficult and why?**
Magnon	That first page still makes no sense to me. The introduction. I could have done all this without the introduction and probably would have been less confused.
Liz	**Which were the easiest and why?**
Magnon	The results were pretty easy. It's just laid right out there for you.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Magnon	I would say if you gave this to the average person off the street they would have trouble with this. It would be a lot of cognitive demand. Particularly that first page though I imagine your target audience isn't just anyone off the street.
Liz	**How do you perceive the overall usefulness of the tool?**
Magnon	I didn't think it was very useful for an individual. If you had a team with different ideas, different perspectives, different needs, goals, different levels of being involved in the process maybe it would help team members see each other's interpretations of needs and values are. But as an individual it's just here are some questions and here are your answers.
Liz	**How do you perceive the amount of time needed to use the tool?**
Magnon	I felt like it was quite a bit of time for what came out.
Liz	**If you used the tool on a future collaborative project, when during the project would you use it and how?**
Magnon	I kind of think it would good to use near the beginning. Just to make sure everyone is on the same page as far as skills and objectives. It may be that one person thinks "oh hey we want to develop this stuff to show at conferences and show our work to the university" and then someone at company E comes back and says "I don't care, we just want to develop it for company E." Stuff like that and have open discussion about what are our priorities and time allocation.
Liz	**What recommendations would you offer an organization considering using the tool?**
Magnon	I would tell them just to go the ranking page and go from there.
Liz	**What characteristics would an organization need to maximize their benefit out of using the tool?**
Magnon	I would think an industry organization that was kind of large and had a lot of contributors.
Liz	**How many contributors are you saying is a lot?**
Magnon	More than 5 people consistently and directly involved in the project. Anything less than five and they can just sit down and have a five to 10 minute discussion on a lot of this stuff and be on the same page.
Liz	**What would you say is the most important thing you learned from using the tool today?**
Magnon	I think there's a wide variety of applications that you can consider doing with your tool. So with any process where you're trying to bring a product to industry there's a lot of variety of goals and objectives and somethings that I haven't even considered, not necessarily relevant to what I was doing but there's a variety of

	things that people can be designing for and goals and objectives and what you're trying to take away from the process.

Simplice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Dimension 7 Step1
Dimension 7 Step 2
Dimension 7 Step 3
Dimension 7 Correct
Dimension 8 Step1
Dimension 8 Step 2
Dimension 8 Step 3
Dimension 8 Correct
Dimension 9 Step1
Dimension 9 Step 2
Dimension 9 Step 3
Dimension 9 Correct

Simplice was a non-native English speaker and Master's student. She was not familiar with absorptive capacity or collaboration innovation networks and had never used Simos' method.

Her scenario was based on a current research project involving 3D printing. This project was stemming from a previous project which she was now taking in a slightly different direction. She saw the project as having started this Fall, only a month ago at the time, and estimated that it would go on for about a year. Simplice was being advised by a Mechanical Engineering faculty but otherwise had no other collaborators on the project. I gave her the option of imagining another researcher at another university which would act similar to her was involved in the project or imagining that her project was collaborative with the manufacturer of the 3D printer she uses as a part of her research. She decided upon the later. We did not choose to identify any specific members of the manufacturer's organization.

Simplice was given the non-concise version of the tool and asked to do an initial review. She noted that it seemed colorful which encouraged her to read more closely.

Simplice was then asked to read the introduction to understand and told that she would be asked to provide a summary when she was finished. During her summary she explains the structure and objective of a collaborative innovation network. She describes how the tool identifies strengths and weaknesses "before the project, during the project, and after the project."

Simplice then completed a workload assessment for this task. She had noted performance and mental demand as her greatest sources of workload followed by effort.

Next, she was asked to complete the context sheet. After reading the instructions (23m 53s), she asked about her what was being referred to, most likely because she was not connecting "organization" as being the "SME" she was representing. She later asked (28m 30s) for elaboration on the meaning of "strategic internal changes" however I did not provide an answer. She can be heard discussing the manufacturer acting as a member of her collaboration innovation network in her scenario while completing the "positions relative to partner organizations on the project."

Simplice then began the ranking sheet. After allowing her to read through the instructions quietly, I then prompted her (33m 6s) to think aloud. She comments that she struggled to figure out step 2 as she did not understand the meaning of a unit, however after understanding that she can have practices at same rank she realizes that same ranked practices would have zero units of difference which is why different ranked practices should have some amount of difference. She later adds (34m 6s) that she was also confused my step 3 but that she would just wait until she got to in within the assessment.

She quickly completes each dimension validating that **she is correct for each dimension** and never receiving any errors. While completing dimension 3 Simplices asks (36m 1s) whether she is allowed to change her responses because she had not previously noticed that there were more practices further down. I told her should could do whatever she would like. Further down (37m 18s) she comments that she feels like between ranks 1 and 2 it should be 1 and between 2 and 3 should also be 1, however the example at the top showed between 2 and 3 as 2 units which confused her. She seemed to believe that between any consecutive ranks there should only ever be 1 unit of difference. This is also evidenced

by the fact that she never chose any values other than 1 for any user inputs for step 2. Her responses and comments otherwise show full understanding of all aspects of step 1 as well as step 3. She even decides to use a decimal value for step 3 of dimensions 3 and 4. At the end she does click the green validation before automatically being navigated to the next sheet.

Simplice had been noticeably quiet during a large part of the ranking process and continues to do so when she reaches the evaluation. I remind her (54m 12s) to think aloud, after which she can be heard walking through her thought process on each practice though not posing any questions.

She then navigated to the results sheet was asked to interpret these. Noticeably she had given most of the practices 4s for capacity and willingness therefore she only had 4 dimension maturity scores which were not 100. However, she was still able to identify those scores that were not 100 as weaknesses, even though they were all above 90. When asked to identify a strength she focused on looking at her overall maturity scores, focusing on the one which had the highest relevancy to context. When asked about her weaknesses, Simplice still preferred to reference the overall dimension but backed in up with specific mentions of practices. She mentions the importance of these practices and that these are connected with her inputs from the ranking sheet, but does not specifically use to help her decide on a plan of action. Simplice was noticeably confused by the maturity grids as it suggested that some practices which she have given a 4 were instead 3s. She felt that her weakness was ultimately due to that area not being very important to her organization at this time in their project. This was also why she thought her organization's willingness for

those practices was low. She thought she and her organization could learn more about these areas, however she did not indicate that this was an overly high priority.

At this point she was given the workload assessment for the second time which was a bit higher this time. She indicated that performance was by far the greatest contributor with mental demand and effort being the runners up.

Simplice indicated she was confused during the ranking, specifically mentioning step 2. She added that ranking many practices at once was more difficult. Simplice found the evaluation the easiest part of her assessment. She felt that a high level of understanding of your project, its goals, and the people you are working with would make using the tool easier. She felt that the tool would be useful to someone who was actually in a collaboration project. Simplice indicated she felt the results justified the time spent. She felt that the tool would be most useful at the beginning of the project and imagined that everyone on the team would use it. It felt that it would be valuable to compare the results of different team members working on the same project within the same organization, though she did not elaborate how so. She felt structured organizations with defined levels of involvement in the project would best benefit out of using the tool. The most valuable thing Simplice felt that she had learned was additional factors which contribute to a project's success, though she did not elaborate upon which ones.

Table 10-35. Simplice Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Simplice	So I'm a research student under Dr. T. I was working on a project and now I've started working another, I've kind of changed my research. Earlier I was working on developing a neural network to predict infill patterns to determine what kind of infill patterns we need to get certain mechanical properties. So that was what I was working on earlier. So now, it still has to do with 3D printing the patterns, so what kind of infill patterns, how the distribution should be according to the load applied. So if there are regions with have more stress we can may put in more infill patterns and distribute the stress more evenly.
Liz	**Is this a collaborative project with a couple different faculty? It sounds like something Dr. F would be interested in.**
Simplice	I haven't approached any other faculty about it.
Liz	**Is this a funded project with industry?**
Simplice	No.
Liz	**At what phase in your project would you say you are?**
Simplice	So this current research I guess started this Fall, so just a month back, so it's pretty much in its infancy.
Liz	**Do you know when your expected completion will be?**
Simplice	Maybe a year from now, but you know how it is with research…
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Simplice	No, I don't think so.
Liz	**What about the notion of a collaborative innovation network?**
Simplice	I don't think so, no.
Liz	**Have you ever used Simos' method?**
Simplice	No.

Table 10-36. Simplice Scenario Development

Liz	**In this scenario, imagine that one of your research projects – namely your current thesis project – is the project being worked on. Everyone at Clemson on your research team including your advisers is part of the SME you are representing. Any other industry partners – which you don't have so we'll need to invent one for you – would be considered other members of collaborative innovation network. So for your particular project, if you were to invite a another university or a particular industry which may have skills you could be beneficial for your project, who would you invite?**
Simplice	Could be anyone…
Liz	**So maybe the easiest thing would be to imagine that there's another researcher at another university with an adviser similar to yours. You can imagine, with your context, what their job might be. This could be based off parts of the project you don't want to do yourself, however you want to imagine it. So your project, it's has a lot of 3D printing stuff, are there any skills you could imagine that bringing in another researcher might be able to help with?**
Simplice	I'm trying to figure out what their input would be, like if we were to try to write a MATLAB code or something. So at this point we don't have anyone involved in that.
Liz	**So is this something that maybe the manufacturer of the 3D printer would be interested in helping with or is it something better to involve another researcher with?**
Simplice	I think maybe the manufacturer.
Liz	**Ok, so for the sake of our study we'll make the manufacturer someone you might be collaborating with on this project. Ok, so any other industry partners – namely the manufacturer of this 3D printer you're working with – which are involved in your project would be considered other members of your collaborative innovation network.**

Table 10-37. Simplice Results Interpretation

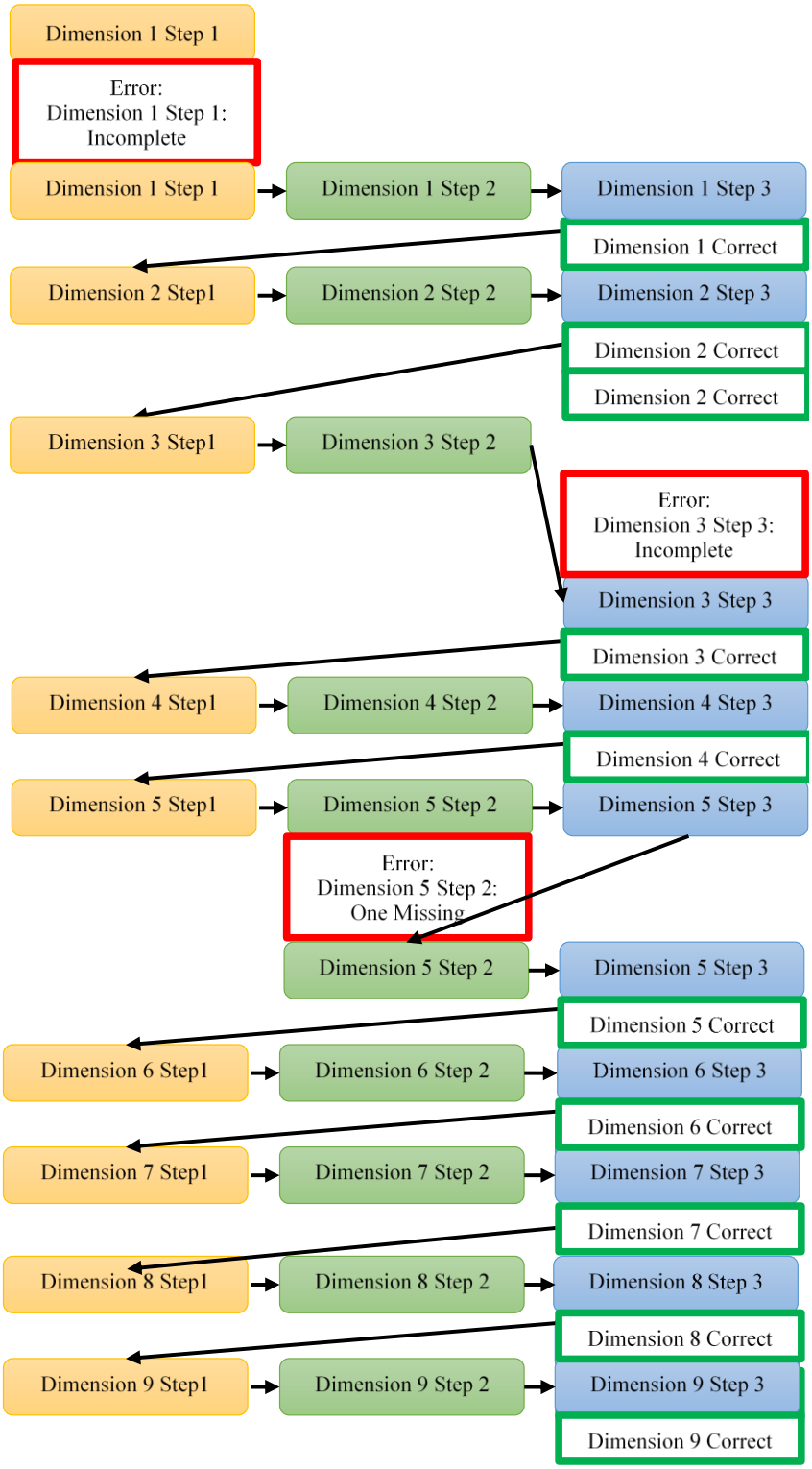
Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Simplice	So I'm reading the percentage shown in the third column and I see that some of these numbers are pretty low, like 20%. And now I'm trying to remember what these were talking about. It's pretty high on capacity and willingness.
Liz	**Can you describe the meaning relative to your project?**
Simplice	So we seem quite capable to do whatever work we need to do on the project. And if we're not capable, the willingness is pretty high so even if we are not capable we are willing to learn. Both of these are low for preparation acquisition. The capacity is 91 and the willingness is 94 which might need some solution maybe.
Liz	**Next, analyze the other figures underneath for each dimension. Describe their general meaning and explain how you would interpret these? Walk me through how.**
Simplice	So these are now ranked based on what I assigned them. So 1.1 I must have given it a rank 1 and depending upon how important the first one is compared to the last.
Liz	**Can you describe their general meaning and how you might interpret them?**
Simplice	So it's about 3 on capacity and about 3 on the willingness… And for this one the capacity is low but we have the willingness and the importance is 10% based on what I ranked it. So this lower right square indicates either we have the capability or the willingness to learn. So these two in application seem to have the same willingness. I don't know if this whole block is for capacity of 3 or if since this is slightly to the right. I don't if one of these was given a higher capacity score. I'm not sure if I'm reading this right…
Liz	**Can you identify an area of strength?**
Simplice	So according to the thematics? I could say learning assimilation seems to be an area of strength because we have the capacity and willingness at 100 according to the maturity scores and the relevance to context was also 100% so I'd say it's pretty important.
Liz	**What do you think is the cause of this strength?**
Simplice	Maybe it was because of things that were in here. Most of the technical stuff and communication. Having communication is important between organizations and using data processing methods so that everyone knows what's going on.
Liz	**Can you identify an area of weakness?**
Simplice	So according to this right here, the table. The preparation acquisition because the maturity scores are low. It has something to do with market knowledge and supply chain knowledge which is not relevant to the project at this point. So that's why the team may not be willing as much to learn things that won't be relevant to the project.
Liz	**What do you think is the cause of this weakness? You may have to reiterate.**
Simplice	The willingness not being there.
Liz	**What action would you recommend that your organization take to improve in an area where it may be weak?**
Simplice	Maybe we need to understand if these will be useful to us in the future – the supply chain knowledge and market knowledge – and try to learn more about them.

Liz	**What action would you recommend that you specifically take to improve in area where you or your organization might be weak?**
Simplice	Maybe try to read up on all this and make an effort to try to understand how it works, the weaknesses. In this case I can see supply chain knowledge and market knowledge, so learning more about the market trends.

Table 10-38. Simplice Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Simplice	It was easy at first but there were sometimes when I was confused. I mentioned about step 2 of the ranking trying to write out the unit of difference and the example didn't make it any clearer.
Liz	**What parts were difficult and why?**
Simplice	So sometimes assigning ranks was confusing and it took me some time to evaluate what ranks should actually be assigned. And sometimes there was just so many, trying to keep all of them in mind and being able to rank them was kind of the tough part.
Liz	**Which parts were the easiest and why?**
Simplice	Assigning the willingness and capacity. That was kind of easy because you have an idea of what the capacity of your organization is or what the willingness might be.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Simplice	It wasn't that difficult if you know what your research or project is and the people you're working with, it's easy to put in everything. You know the goals.
Liz	**How do you perceive the overall usefulness of the tool?**
Simplice	I think it's pretty useful if someone is actually in this kind of a situation where they are collaborating with someone working on a project to understand what needs to be worked on or what are the strengths of the organizations.
Liz	**How do you perceive the amount of time needed to use the tool?**
Simplice	I think it's not much time in return for the results you get.
Liz	**If you used the tool during a future collaborative project when during the project would you use it and how?**
Simplice	I think I would use it at the beginning of the project to understand what the strengths are because I'm assuming that everyone on the team will be using the tool and then all the results together will help understand the strengths and weaknesses of the organization or team.
Liz	**What recommendations would you offer an organization considering using the tool?**
Simplice	It's important that they know what their goals are and that they know their team well and their capacities. They should know what is expected of them.
Liz	**What characteristics would they need to maximize their benefit out of using the tool?**
Simplice	A structured organization with collaboration at different levels and the project should be well defined and they should know what goals they are looking to achieve.
Liz	**What would you say are the most important things you learned from using the tool today?**
Simplice	I thought more about what it takes for a project to be successful and it gave me some insight about that.

Toussaint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Toussaint was a native English speaker and Master's student. She was not familiar with absorptive capacity or collaboration innovation networks and could not recall having used Simos' method.

Toussaint scenario was based on her Master's thesis project under a Mechanical Engineering faculty. The project involved designing a robot with new capabilities. She was currently in the final phases of the project and was working on testing of a recently completed prototype. This project was in collaboration with industry.

Toussaint was given the non-concise version of the tool. Early within her initial review of the tool (5m 45s), I note that she is making some sort of face. She comments that she had not realized it was multiple sheets. Soon after she comments that she is impressed with the usage of buttons within the tool. At the end of her review (7m 23s), Toussaint comments that the tool seems detailed.

Toussaint was tasked with reading the introduction and was told she would need to provide a summary when she was finished. She had no commentary during this time. Toussaint's summary included defining what a collaborative innovation network and what objectives of the tool was.

She was then asked to complete a workload assessment. Toussaint indicated that her highest amount of workload came from performance and from mental demand.

Toussaint then began completing the context sheet. Based on her commentary she seems to be correctly using the scale provided. Upon reaching the context statement regarding "knowledge about a component of solution" she comments (21m 33s) that "I don't necessarily understand what that's asking." She think about the question a bit more

about then indicates a somewhat high level of agreement. Upon reaching the statement regarding "intellectual property," she begins referencing (23m 37s) her partner company and imagining aspects of their partnership. While deciding upon her response to the last context statement (26m 6s), she comments that "I have no idea on that one, that's why I'm putting it in the middle."

Toussaint then begins reading the instructions within the ranking sheet. She notes (27m 37s) that she "doesn't necessarily know what 'thematic' means" which was causing her some confusion. She then added that she was going to think of the word as being "theme" and that the themes referred to the "acquire" and "assimilate" and "something else." Toussaint can be heard reading (30m 36s) in the instructions that consecutive ranks are required, and that same rank is allowed. "So does that just mean you can't go 1, 4, 7, it has to go 1, 2, 3?" She then confirmed that she understood that this was the case. Toussaint later summarizes her understanding of step 2 saying "so you can space them out as far as you want but it's still rank 3."

She then begins working on the first dimension. After noticing the practice index numbers (34m 2s) she notes that "these aren't in order" indicating that she does not understand that some practices are hidden. Soon after she asks (34m 29s) "I don't have to add anything right? These blanks spaces are just blank? You can't answer that question? Am I supposed to just make up stuff? I'm just going to fill out what's there. Or I guess I can refer back to the instructions…" Later Toussaint comments that (35m 11s) "The 9 thematics, they're all the same, just in a different box." She then appears to test the capabilities of the red validation buttons and clicks (35m 41s) it once finding that

dimension 1 step 1 is still incomplete. Satisfied she continues working on the rest of the dimension. She struggles to figure out the meaning of step 3 and distinguish its meaning from step 2. She considers the example figure from the instructions a bit more but cannot make sense of it. She decides to sum her responses from step 2 to get her answer for step 3. Toussaint then clicks the red button and finds that **she is correct**.

Toussaint then moves on to dimension 2 where only 2 practices are shown. She comes close to putting the two at the same rank (41m 3s) commenting that they have no difference, but then thinks about it a bit more and changes her response. She correctly completes steps 2 and 3. Her response for step 3 which was a decimal value close to 1 shows that she no longer things that step 3 has the be the sum of her responses for step 2. She **validates this dimension twice** before moving on the next dimension.

During dimension 3 she does decide to use same rank with step 1 (46m 4s). She forgets to complete step 3 before she clicks the red button (47m 13s) but quickly goes back and does so **before revalidating**.

Toussaint then begins dimension 4 realizing (47m 53s) that she is back to acquisition but within the achievement phase. She correctly completes this dimension and **validates when she is finished**.

She then goes on to dimension 5. Three practices are shown, however she only choses to use two ranks resulting in only one pair of ranks to consider in step 2. The first time Toussaint completes the dimension she does not put a 1 for this unit of difference so the button notifies her (51m 32s) that **at least one of the pairs of ranks from step 2 must be defined as 1 unit**. She adjusts her responses and then finds that **she is now correct**.

Toussaint goes on to **correctly complete dimensions 6 through 9**. She notes (55m 6s) that she is not sure what "intermediary forms of communication" was referring to within dimension 8. At the end, Toussaint does click on the "Ready to Calculate" button.

At the start of completing the evaluation (1h 5m 53s) she comments that she is evaluating both herself and her faculty adviser together. She complains about the frozen headers (1h 6m 41s) being a problem due to a scrolling issue with her mouse. Toussaint then begins to narrate her thought process while she completes the evaluation, specifically mentioning her other collaborators in some of her considerations. At the end she reads the instructions regarding the green button but while doing so clicks the button. She seems to realize that she had already done this, and it was not required to do it again though was unconcerned by it.

Toussaint was then asked to interpret her results. When looking at her scores she felt inclined to consider them as an ABC score meaning that values above 80 or 85 were good while everything else needed improvement. She complained that she did not know where she really wanted her scores to be. When reading the instructions for the lower half of the results sheet, she figured out that the importance percentages were based off the ranking she gave. Toussaint noted that the multiplier she gave for step 3 for the first dimension did not align with the calculated percentage values which confused her. This may or may not have been an error in the calculations. When looking at the maturity grids, Toussaint focused on practices in the red areas, but considered them in terms of their importance. She identified one red practice as something she did not care about due to its importance percentage and identified another practice in yellow as needing action because it was

particularly important. When asked to identify strengths her response was somewhat vague. She identified that she was a willing and capable learner and felt that this was due to her curiosity. She then identifies her weakness as not being willing to change her personal views and letting personal feelings get in the way. She then realized that her statements were contradictory and asked to change her response to the question about her weaknesses. Toussaint then identified that instead of her previous response that her weakness what that she gets distracted easily. Then realizing that the questions were pertaining to her organization's weaknesses and not specifically her own, she changes her response again. This time she states that her weakness was in organizational skills between people. She felt that she was good at organizing herself but not is organization collaboration with others. She noted that the reason for this weakness was that her organization does not communicate enough and that she tends to be vague in her communications. She struggled to identify improvement actions initially but eventually settles on wanting to set up a structured communication plan and regular meetings. She thought that if she recorded more of her thoughts in a written format more often it would help improve in this area as well.

At this point, Toussaint was given the second workload evaluation. This time she noted having the same level of performance demand but having much higher mental demand. With the exception of physical demand, all of the workload measures were noticeably higher for this second evaluation.

Toussaint felt that the tool was a little confusing but could be figured out if you play around with it. She found the ranking the most difficult and felt that it was difficult due to her own intelligence. She identified the context as being slightly easier than the evaluation.

Toussaint felt that the tool required a decent amount of effort but defended it by saying that "You want someone to put effort into it because otherwise the numbers are meaningless." She noted that the tool had not been particularly useful to her research, however it could be useful for larger organization. She stated that "it's as useful as the person putting the time in I guess" and generally felt that the time was acceptable. For a future collaborative project she felt that the tool would be most useful as soon as she had a team organized. She recommended that if an organization was considering using the tool that they should have a training session on it beforehand. Toussaint thought the tool was most useful in very collaborative environments where there is a lot of knowledge sharing towards a particular objective and that it was not particularly useful for individuals working towards their independent goals. The most important thing she felt that she had learned while using the tool was thinking about the importance of practices without personal bias though she notes she was not completely successful at doing this.

Table 10-39. Toussaint Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Toussaint	I'm working on a robotic leg, specifically a compliant mechanism with adjustable lengths.
Liz	**Is this a project you're working on with industry or someone else?**
Toussaint	It's just my thesis project.
Liz	**Whose student are you?**
Toussaint	Dr. W.
Liz	**So are you outside of the design lab?**
Toussaint	Yeah.
Liz	**Have you taken a design and/or product development course in the past few years?**
Toussaint	Yeah, ME 8070.
Liz	**Ok, so this product is under Dr. W. Do you have any other collaborators?**
Toussaint	I'm not sure the definition of collaborators. I worked with an undergrad who helped me build some stuff.
Liz	**I'd say that counts for this. Is this a funded project?**
Toussaint	No.
Liz	**Is it for a particular client that may be collaborating with you?**
Toussaint	No, this is funded by Dr. Wagner's own research funds.
Liz	**Are you working on any other projects?**
Toussaint	Yes and no. Dr. W has been working on this PLM center, product lifecycle management center, and I've worked with her to develop some materials for that which is in collaboration with outside industry.
Liz	**Would you say that you're well informed on that project? The expectations and the collaborators.**
Toussaint	No. That was what I was working on when I first got here and…
Liz	**It got shifted in a different direction?**
Toussaint	Yeah. I still do a little bit on it every once in a while but…
Liz	**Regarding your thesis project, what phase in this project would you say that you are?**
Toussaint	Prototyping I guess. I've designed it and I've built the prototype. Now I'm working on testing the prototype.
Liz	**Do you know when the project started?**
Toussaint	Last Spring.
Liz	**Do you have an expected completion date?**
Toussaint	December.
Liz	**Are you familiar with the concept of Absorptive Capacity?**
Toussaint	I can't say I've ever heard of it before.
Liz	**How about the notion of a collaborative innovation network?**
Toussaint	Meh.
Liz	**What would you say it is? Have you heard of the term before?**
Toussaint	No.
Liz	**Have you ever used Simos' method?**
Toussaint	Maybe. I don't remember names necessarily.

Liz	**Do you want to hedge a bet?**
Toussaint	I don’t know.

Table 10-40. Toussaint Scenario Development

Liz	**In this scenario, imagine that one of your research projects – namely your actual research – is the project being worked on. Everyone at Clemson on your research team including your advisers is a part of the SME that you are representing. Any other industry partners which are involved in your project, which you don't have any so we'll have to come up with some theoretical ones, would be considered other members of your collaborative innovation network. Do you have any clients who might be interested in your research or if you were to pick the ideal collaborator who that might be?**
Toussaint	I haven't had any discussions with them but what commonly comes us is company B or other biped locking robotics companies.
Liz	**So let's say company B was funding your research for a similar objective to what you're currently working on. How would you describe their role on the project or what their contribution might be.**
Toussaint	Well they have a lot of expertise in that area with controls and robotic things.
Liz	**Ok. So any other industry partners involved in your project – namely company B – would be considered other members of your collaborative innovation network. So to reiterate, everyone at Clemson on your research team including your advisers is a part of the SME that you are representing and company B would be a part of your collaborative innovation network.**

Table 10-41. Toussaint Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project.**
Toussaint	Maturity scores are shown in the first two columns. 68, seems like an F. What is a low score? Is it based on an ABC kind of thing? Oh but the relevancy is only 40% so who cares. Application: can I use it, who cares.
Liz	**To reiterate describe the meaning of these results relative to your project.**
Toussaint	I am 100% willing to "achievement acquisition" but my capacity is only at a 69%. None of them are above 80 except for one. Learning application: I am capable of learning things. That's good. All the other ones, the most relevant is learning assimilation at 80%. The least relevant is achievement application at 30%. 40% for preparation acquisition and preparation assimilation but 68, 75. I guess I don't really know where I want my scores to be. At 100? I guess if it's a zero to one hundred scale I guess you want it to be above 80. Probably above 85. So I need to improve on everything except for being able to learn and apply what I learned and I am willing to do that. That's my interpretation of these results.
Liz	**Next analyze the other figures underneath for each dimension. Describe their general meaning and explain how you would interpret these. You don't necessarily have to interpret each one but if you could give me some good examples.**
Toussaint	So we have one that's judging my willingness/capacity in a square kind of thing. And you've got the other one here showing importance based on my rankings and my first to last, last to first multiplier. So I said, times 2, times 3 for that for that first one I think. Well I guess it's times 4.8 but I know that's not what I gave it. So I guess this is telling me that I don't have a lot of capacity for these things but I am willing. And these things I have capacity and I have willingness. You want to be in the green. And the yellow is okay, but the red is bad. You really don't want to be in the red, that's what I'm getting here. If you are in the green you are capable and willing. Do I have any in the red? Oh no. 3.14 is in the red. But it's only 4% important though so whatever. These are all in the green? Look at that, that's pretty good. The most important one is in the green. Ah 3.19 is in the yellow and that's my top third one. Yeah that's because I'm not a business major. It's actually pretty easy to figure out, especially these ones. You can kind of quickly look and say "hey, look at these" like that one. And then you can line it up with your importance and say "but do I really care?" Obviously not.
Liz	**Please identify an area of strength. And what do you think is the cause of this strength? But first identify it.**
Toussaint	So I am a very willing learner.
Liz	**What is the strength that you're identifying?**
Toussaint	My capacity to learn.
Liz	**Ok, what do you think is the cause of this strength?**
Toussaint	I am very curious about things and I want to ask people questions so they can educate me.
Liz	**Can you identify an area of weakness?**
Toussaint	Yes, I can. Working with the customer.
Liz	**I see you're looking at the practices.**

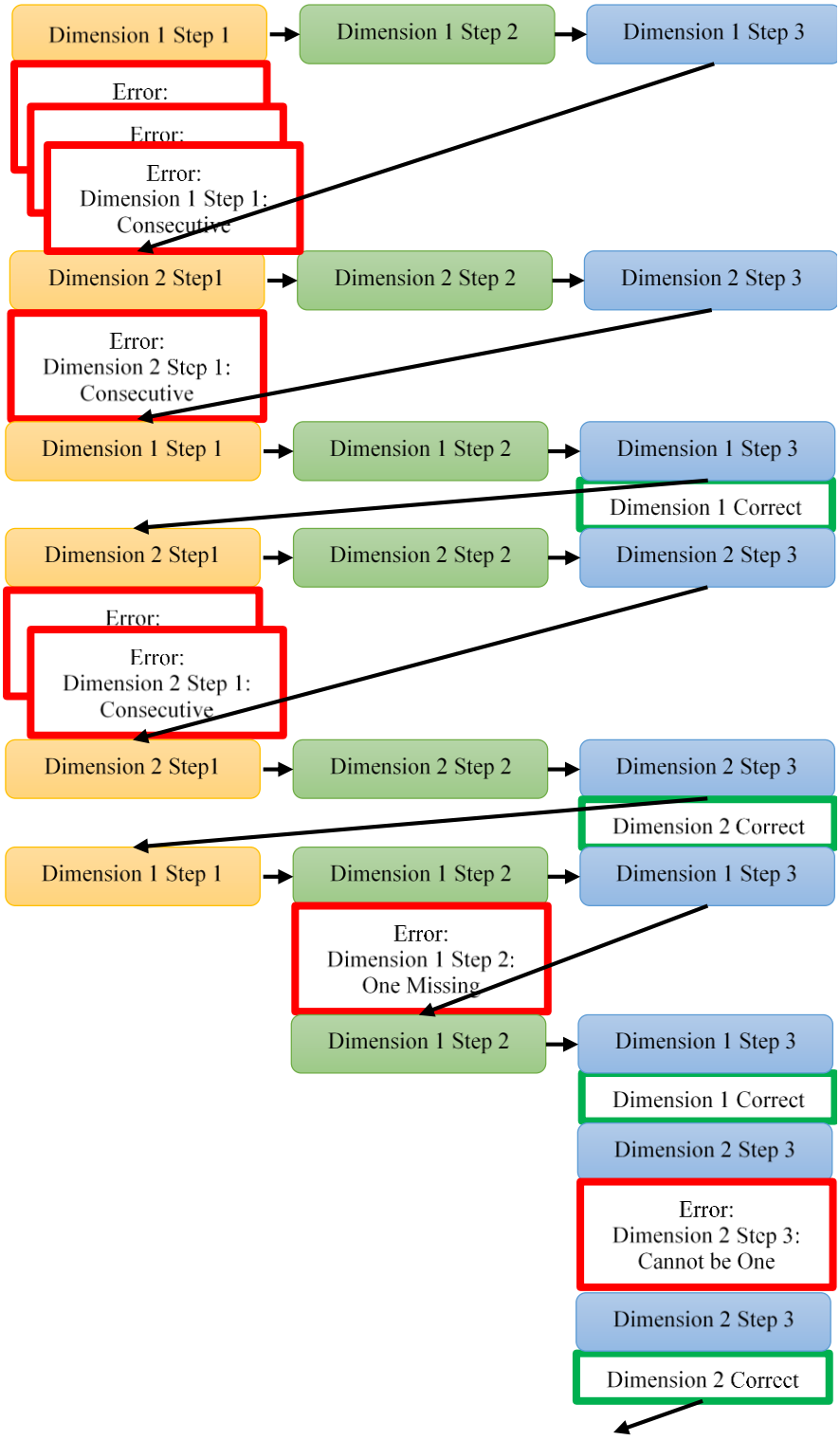
Toussaint	Yeah, and changing my personal views for the better. Oh I am kind of understanding this more. Not letting your personal feelings get in the way. Yeah, that's definitely a weakness right there.
Liz	**What do you think is the cause of this weakness?**
Toussaint	I don't like change. I don't like necessarily trying to change the way I think about things.
Liz	**What action would you recommend that your organization take to improve in an area where it may be weak?**
Toussaint	I just realized that I contradicted my strengths and weaknesses. I said I love to learn and have people teach me things and then I said I don't want to change my ideas so that was kind of dumb. But that's one of my weaknesses.
Liz	**What action would you recommend that your organization take to improve in an area where it may be weak?**
Toussaint	Sorry. Not thinking long enough. I regret my answers to the last two questions.
Liz	**You're welcome to change your answers if you so choose.**
Toussaint	So my weakness isn't that I won't change my personal objectives, it's that I get distracted easily. I don't know. But that's not necessarily organizational.
Liz	**To reiterate that question, please identify an area of weakness.**
Toussaint	Yes, area of weakness. Is organizing, what was one of these things, organization skills between people. I can organize my own stuff but then organizing collaboration with multiple people is difficult.
Liz	**What would you say is the cause of this weakness?**
Toussaint	Not communicating enough clearly. Being vague.
Liz	**What action would you recommend that your organization take to improve in an area where it may be weak?**
Toussaint	We should organize a meeting to talk about these things. Or set up a structured communication plan. A structure for how we communicate. And regular meetings.
Liz	**What action would you recommend that you take to improve in an area where you or your organization may be weak?**
Toussaint	How am I supposed to know? How do I get better at organizing communication? How do I do that? Take a class. That always works. Go to a seminar. Write down things, record things more often, I try to keep everything in my head instead of keeping track of it with written things that will remind me.

Table 10-42. Toussaint Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Toussaint	There were a couple things that were a little confusing. But overall, I think if you just play around with it you can kind of figure it out.
Liz	**Which parts of the tool were the most difficult and why?**
Toussaint	This one was the most difficult. The ranking. Yes, just because I didn't fully understand it. Maybe because I'm dumb. This one, the evaluation, was pretty easy to understand, not difficult, but sometimes it just felt…
Liz	**Which parts of the tool were the easiest and why?**
Toussaint	I forgot about this one, the context, that wasn't too hard though, that was pretty easy. I would say context was easier than evaluation, although results if we're really talking about the easiest…
Liz	**How do you perceive the amount of effort needed to use the tool?**
Toussaint	Do I think it's a lot? You want someone to put effort into it because otherwise the numbers are meaningless. Or relatively, I guess it's all kind of arbitrary. But if someone is actually thinking about what they are doing and putting there instead of just using a random number generator. How do I perceive the amount of effort, it requires a decent amount of effort but that's kind of the point.
Liz	**How do you perceive the overall usefulness of the tool?**
Toussaint	Well for my research is wasn't but… it was pretty useful. It's as useful as the person putting the time in I guess. Some of the things… I'm trying to think about it in the scope of a larger business than just my research.
Liz	**How do you perceive the amount time needed to use the tool?**
Toussaint	It took about an hour, right? Hour and a half maybe? Which out of a day, if this helps your SME's abilities to, or identify your weaknesses and improve upon them, wait, what was the question?
Liz	**How do you perceive the amount time needed to use the tool?**
Toussaint	Not that bad.
Liz	**If you used the tool for a future collaborative project, when during the project would you use it and how?**
Toussaint	I would I guess if I had everyone, a team together for a planned project have them each of them individually and together and compare and come to a consensus.
Liz	**What recommendations would you offer a recommendation considering using the tool?**
Toussaint	Do exactly what I just said. Maybe have a training session on it as they are introducing the new thing.
Liz	**What characteristics of an organization would they need to maximize their benefit out of using this tool?**
Toussaint	Well they'd need to have a very collaborative environment where people are sharing knowledge and skills and working together to meet a goal. As opposed to individuals working on individual projects doing their own thing and not really working together.
Liz	**What would you say are the most important things that you learned from using the tool today?**
Toussaint	How to rank things. What the word thematic means. I would say ranking things and how to perceive which is more important without my bias which I didn't

	succeed in doing but I did learn that you want to rank things based on the project and not my thoughts personally.

Zéphine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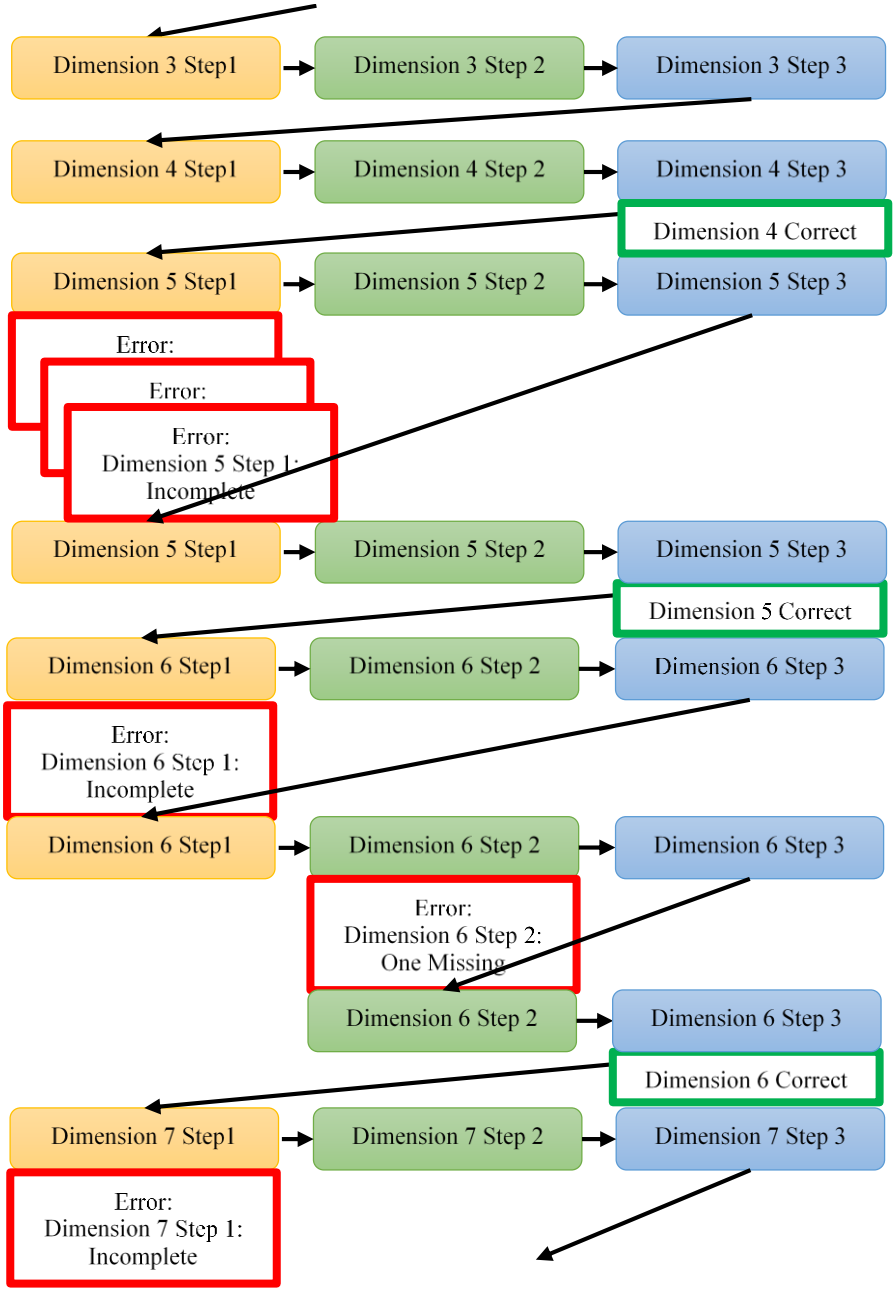
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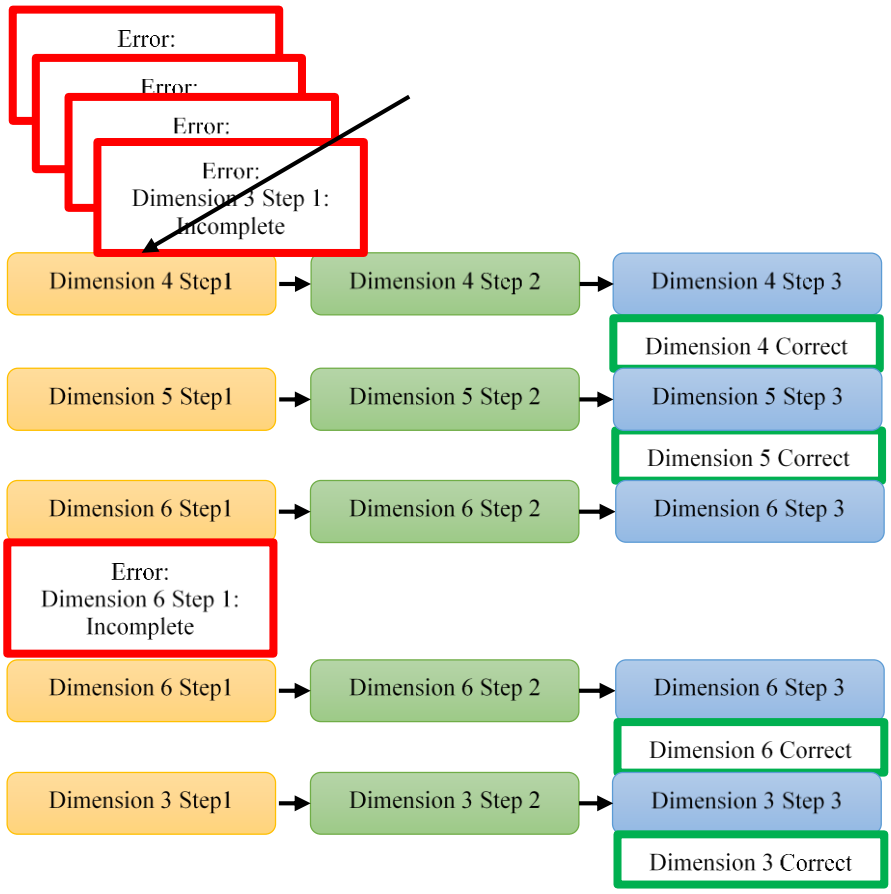
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Zéphine was a non-native English speaker and PhD student. She was not familiar with absorptive capacity but had some idea about collaboration innovation networks. She had, however, never used Simos' method.

Zéphine's scenario was based on her PhD research project involving solving packaging problems of wire routing in confined environments. The project began August of 2014 and would end August of 2019. She claimed she was complete with the first phase and was mid-way through the remaining two phases. She added that she was in the implementation phase and was expecting results soon. Zéphine noted that an outside company had provided the initial motivation for the research though they were not involved in the project's current direction. She was asked to imagine her project as if this organization had decided to continue being involved and to consider this organization as part of her collaborative innovation network. I mentioned her adviser as being part of her research team at Clemson following my script, though I failed to specifically get her to identify this adviser herself as I already knew who it was.

Zéphine was given the non-concise version of the tool. She quickly reviewed the tool and had no comments to give at the time.

She was then told to read the introduction for understanding and notified that she would need to provide a summary afterwards. She noted (7m 42s) that she did not know what "assimilate" means. She was encouraged to keep asking questions though I told her I could not answer her at this time. When she finished (13m 9s) she gave her summary of the tool, noting the objective of the tool being to evaluate knowledge absorption to propose ideas of ways to improve in weak areas. She notably mentioned that this was based on 9 "practices,"

though discusses that there are three phases: preparation, achievement, and evaluation. She seems to be struggling with using the terminology correctly but does seem to understand what the tool does, though maybe not how it does it.

At this point she is asked to assess her workload for this task. She indicates that performance is her primary source of workload with mental demand being second.

She is then prompted to begin working on the context sheet. Zéphine comments that she is not sure if she understood the first one but is able to reasonably interpret the question despite that I was not able help her. She narrates her thought process, mostly unintelligibly reading the questions though occasionally indicating either "yes" or "no" depending upon how she felt about the statement. Based on this, she appears to have correctly used the scale. She noted (23m 20s) that the 1 to 6 scale did not have a neutral value which forced some of her responses.

Zéphine was then prompted to complete the ranking. She identified a typo (24m 8s) in the first sentence but it is not clear where this typo was. She is then quiet for three and a half minutes while she processes the instructions before I prompt her to tell me what she is thinking about. At this point she comments that she does not understand the meaning of the instructions for step 3 or why it is necessary based on her understanding of step 1. She is then quiet again for another minute and a half (29m 35s) before she reiterates that she does not understand step 3 but does note that she feels she understand step 2.

It should be noted that although Zéphine spent a reasonable amount of time thinking about each step, she very quickly processed the error messages which made it difficult for me to capture all of the ones she was receiving. Thus, the map of Zéphine's error messages

and their quantity may not be perfectly accurate. It was particularly difficult when she got closer to figuring something out as she would click on the button multiple times. For the sake of time I eventually had to ask her to move on to the evaluation before she had completed all dimensions of the ranking, however her very last actions and comments indicated that she at least properly understood the process at that point. It is assumed she could otherwise go back and complete the rest of the dimensions if she had been given more time, though was not allowed to do so.

Upon beginning to complete step 1 for the first dimension, Zéphine comments that she is confused by the empty white space but can then be heard (30m 55s) saying that "I have 5 fields and my ranking should be from 1 to 5." This shows that she does not yet understand that the ranks can be same rank. Zéphine completes the rest of the dimension and then notes that she will now click the red button. She initially does not realize that the message was **an error** but quickly figures it out. She **clicks on the red button a couple more times** as she wants to review the message again. Each time the message was about step 1 being nonconsecutive. Instead of changing her values, she decides to try dragging and dropping practices (34m 23s) seemingly still confused by the white spaces between practices. She notes that she needs a password to make this edit. She later adds (35m 3s) "I'm doing something wrong and I cannot figure it out. I think I'm going to do all of them and then figure that out."

Zéphine then proceeds to the 2nd dimension where only 2 practices are shown. She comments (35m 7s) that she is unsure if these practices are things her organization is already doing or should be doing, noting that the header suggests that these actions prepare

for the future. Zéphine indicates (36m 45s) that she is going to put a 1 next to the most important practice, however notes that the second practice was not relevant to her context and gives it a rank of 4. She can then be heard thinking about step 2 where she notes that "between 1 and 2 is 3 and this is zero and this is zero. There is no rank 2 so, zero. This is a little confusing." It is believed that Zéphine puts 3 units between 1 and 2 and then puts zero between 2 and 3 and between 3 and 4. Upon reaching step 3 (37m 44s) she adds that she now think she understands what it means. She goes back to her answers for step 2 and adjusts her responses. She then clicks the red button and **gets an error message about step 1 being non-consecutive**. She can be heard discussing step 2 a bit further eventually deciding on 1 unit between 1 and 2.

Not sure how to fix her error, Zéphine decides to go alternate back and forth between dimensions 1 and 2. She can be heard saying (42m 51s) that maybe her error is because she is missing a 3 in step 1. She adjusts her responses and then adds "Maybe it's not working because it has to be consecutive." She refers back to the instructions quoting that "the number of ranks is not fixed" and that she does not understand what this means. She adjusts her responses seeming to put a zero in step 2 before correcting it to be 2.

Following the audio it is impossible to follow her error messages with her commentary. Upon deciding to go back to dimension 1 she is noted to have edited and have found that **she was correct**. She then goes back to dimension 2 where she **gets two error messages about step 1 being nonconsective** before being able to **correct her responses and revalidate**. She noticeably decides to go back to dimension 1 which had previously been correct and change her responses so that **she got an error in step 2** about at least one pair

should have a 1 unit of difference. She corrects it again and **finds it to be correct**. She then returns to dimension 2 where she had also previously found herself to be correct and evidently **changes step 3 to be 1 triggering an error**. She changes her responses again and **revalidates dimension 2**. She can also be heard working on dimension 3 during this time however she forgets to click the red button for this dimension at this time, assuming it was correct. She later references this dimension as having found it correct though that was not the case. This is responsible for a lot of the confusion that she will have during future dimensions.

She notably completes dimension 4 which had 3 practices on her first try and **finds it correct**. She had given both differences in step 2 only 1 unit and gave the lowest rank's numerical value for her answer to step 3.

Zéphine moves on to dimension 5 where she struggles to figure out that all user inputs in step 1 are required to be complete and **triggers 3 errors** about this issue before being able to validate that **she is correct**.

During dimension 6 she triggers the error that **step 1 is incomplete again**. She fixes this problem and then triggers another **error that step 2 is missing a smallest difference of 1 unit**. She is able to correct this and **validates the dimension**.

She completes dimension 7, again triggering the message that **step 1 is incomplete**. At this point she decides to go back to dimension 3 to see why her logic had worked there but not here, finding that she actually had **made an error** in dimension 3. She triggers the same **incomplete message 3 more times**.

She then returns to dimension 4, **finding it to be correct again**. Moves to dimension 5 and similarly **finds it correct again**.

She then returns to dimension 6 and gets the error message about **step 1 being incomplete** another time before then **completing it correctly** and being able to validate. She then returns to dimension 3 and is able to **complete it correctly**.

At this point I stop her as I am struggling to keep up with her errors and I have run out of space on my note sheet to continue noting them. Based on her comments and her responses to dimension 3, she gave evidence that by the end of the time spent doing this process she fully understood that step 1 required all user inputs to be complete in a consecutive fashion with 1 being the most important. She was also able to use same rank for this dimension as needed. For step 2 she illustrated that 1 was the smallest difference, that multiple pairs could share this smallest difference, and that some pairs could be bigger than this amount. For step 3 she did consistently choose to have this value equal to her lowest rank so it is unclear if she fully understood this step.

After allowing her to get to this point where she understood most of the process, I decided to intervene (1h 8m 12s) for the sake of time. I modified the evaluation task so that she would only need to complete dimensions 1 through 7. All of these dimensions had been found to be correct during the ranking process however she had left values in some white cells under step 2 within dimensions 2 and 6. This error gets ignored within the calculations and was allowed to remain. Other than indicating that she had mostly figured out the ranking process, I did not explain what parts were wrong or elaborate on the ranking

process at this time. Dimensions 8 and 9 had no values and would eventually be shown having scores of zero on her results as a result of not having completed them.

Most likely due to the interruption before the end of the ranking process, Zéphine had not clicked on the green calculation button at the end of the ranking sheet. However, after reading the instructions on the evaluation sheet, she realizes this (1h 9m 50s) and chooses to click on the button on this sheet. After it calculate she proceeds with the evaluation narrating her thought process as she goes.

Zéphine is this prompted to interpret her results (1h 20m 37s). She is able to identify dimensions of high capacity and wiliness, identifying that the application dimensions are a weakness for her organization. She is notably one of the few users who both notices and also correctly interprets the importance ratings. Zéphine even draws the connection between the importance values being connected to the ranking process while the capacity and willingness maturity grids are based on the evaluation. She does decide to go back to the evaluation briefly to verify the connection. She notes that she will focus on the red ones and maybe consider the yellow practices specifically contextualizing her interpretations using the importance percentages. Zéphine choosing to identify a particularly important practice that she was also mature in as her strength and was able to relate this back to her project. She determined a weakness involving marketing to the end user which she felt was because there was no wiliness to do that at the current stage of her project. She noted that her organization could do a better job of studying the end user and the effects her project would potentially have. She commented that she should consider more of the usability of the knowledge she was creating in her project to identify how it will be used and what

obstacles industry would face in trying to implement her work. Zéphine added that organizations considering to use the tool should first be willing to collaborate. She thought that using the results of the tool from past projects could help provide a useful comparison. She also felt that organizations with separated departments could use the tool internally and the university research teams, particularly interdisciplinary ones, could benefit out of using the tool. She indicated that felt it was “a good thing that I came across this tool” because it helped her to think more about the end user which she felt was important.

Table 10-43. Zéphine Initial Interview Responses

Liz	**What research projects are you currently working on? Describe them briefly.**
Zéphine	So my work is numerical. I'm trying to build an algorithm to solve the problem of locating breakouts for cable harnesses and routing wires in compact environments.
Liz	**Is this a project that is collaborative with industry?**
Zéphine	No.
Liz	**Is this the company A project?**
Zéphine	It's their academic problem but now it's moving towards routing.
Liz	**Is it a funded project by anyone?**
Zéphine	No longer funded.
Liz	**At what phase in the project would you say you are?**
Zéphine	Can you define phases?
Liz	**You can define them however you'd like. I'm trying to gauge if you're early in the process or late in the process.**
Zéphine	So the project had three phases. I've done the first phase and I'm working on the last two. And on those two phases I think I'm right in the middle, I'm in the implementation phase. I'm going to start getting results soon.
Liz	**Do you know when the project started?**
Zéphine	2014 in August.
Liz	**Do you have an expected completion date? I know that's sometimes a bad question to ask.**
Zéphine	August of 2019.
Liz	**Are you familiar with the concept of absorptive capacity?**
Zéphine	No
Liz	**How about of a collaborative innovation network?**
Zéphine	I've heard about it.
Liz	**Do want to take a wild guess as to what it is?**
Zéphine	A collaborative network, if you have a team consisted of people of different disciplines that would be an example of a collaborative team.
Liz	**Have you ever used Simos' method?**
Zéphine	I haven't heard about it, no.

Table 10-44. Zéphine Scenario Development

Liz	**In this scenario, imagine that one of your research projects – your PhD research – is the project being worked on. Everyone at Clemson on your research team including your advisers are a part of the SME that you are representing. Any other industry partners – in this case we're going to count company A as this separate industry. Imagine that they were still involved in the project. You may have to use your imagination for that, and that's okay. Any other industry partners involved on your project – namely company A – would be considered other members of your collaborative innovation network.**

Table 10-45. Zéphine Results Interpretation

Liz	**Read the instructions and examine the radar chart and table next to it. Describe the meaning of these results relative to your project. So ultimately we're only going to be able to look at the first 7 so if you got a zero just ignore it.**
Zéphine	I understand that these come from the three phases.
Liz	**Can you describe the meaning of these results relative to your project?**
Zéphine	Ok, so you just want me to describe it? Ok. Preparation acquisition capacity is high. So the organization is acting maturely I guess in the preparation phase because I can see the capacity is high. And we're willing to try a lot of the practices. In the learning phase, we're also doing good. Achievement application, okay I think this is because there's not much capacity to interact with the end user or marketing the final outcome of the project and they're not that willing to do that at this point. So that could be the reason why in the achievement application, the level is not that mature. But for the rest I think we've got high capacity and we're willing to try the thematics.
Liz	**Next, analyze the other figures underneath for each dimension. Describe their general meaning and explain how you would interpret these. Ultimately walk me through how you would interpret a few.**
Zéphine	Ok, so these are the importance I gave. Ok, so there's the capacity and willingness and there's the score I gave. Ok, I understand it now. So this table is the score I gave based on the importance ranking. Yeah, that's what I gave. And this is the capacity and willingness score based on the evaluation. So for my project, for the acquisition phase, of the preparation, our most important are exploring the techniques and… can I go back to the evaluation?
Liz	**Yes.**
Zéphine	So I have a 4 and a 3, so.. okay, this makes sense. So 1.1 is the most important practice is the acquisition phase and I gave it a 4, but in capacity it's 3. Oh it's the opposite. Capacity is 4 and the willingness is 3. Okay this is a little confusing, I'm not sure which is the capacity and which is the willingness. I can see that but… I know it's between 3 and 4 but I cannot say whether it's 3 or 4. But I can say it has a higher score. So the next one, it's clear, 1.9. So I can say it's roughly 3 or 4. So next is 1.6 which is as important as 1.9. So I guess it's capacity is less than 1.6. So supply chain knowledge isn't that important so the capacity and willingness is not that high. That makes sense. Exploring market knowledge, yeah, not that important. So there's not much capacity but there is willingness. So I guess, if I wanted to do something I would focus on the red ones and then maybe look at the yellow and then maybe look at the importance to see if I'm doing a good job. Like, for here, the importance of 1.2 is not that high but maybe I could move it to yellow. Here I don't have any red so I'll focus on those first. Here I have one. Okay, 5.1, oh but it's not that important so we could work on the capacity and willingness because they aren't that good. And here, I can tell from the previous chart too that we didn't do very good in the application. And we have this one that's very important at 50% to promote the innovation at events to facilitate communication with the target market, yeah we need to work on this. We have the willingness but the capacity is low. And this 7.3, oh it's 2% so I probably won't worry about it.
Liz	**Can you identify an area of strength?**

Zéphine	I can. So based on the importance, here I have an importance of 50% on organizing exchanges between participating organizations and we are both willing and have the capacity for it.
Liz	**What would you say is the cause of this strength?**
Zéphine	I guess it comes from the nature of the project. So we collaborate and meet to exchange knowledge. So it comes from that need. So we figured out there was a need for it and we started by collaborating by having meetings, by exchanging the knowledge. There was capacity because there was a need. So we're willing and I see that we're doing a good job there.
Liz	**Can you identify an area of weakness?**
Zéphine	Like I said, it's the marketing to the end user. It could be kind of important when it comes to the promoting the innovation and doing events.
Liz	**What do you think is the cause of this weakness?**
Zéphine	Because there's no willingness to do it even with it being important. Right now they're only focused on the technical side of it and not the end user side.
Liz	**What action would you recommend that your organization take to improve in an area where it might be weak?**
Zéphine	So I think they should start by studying the end user and the effects of the project on the end user. So the process of designing something and the rules for it, can an end user implement this new knowledge in the everyday designing and assembling of the wire harnesses.
Liz	**What action would you recommend that you specifically take to improve in an area where you or your organization may be weak?**
Zéphine	So I think I could take the lead on studying the usability of this knowledge and trying to reach out to people in industry to find out how this knowledge can be used and what obstacles exist in industry in taking a new algorithm into practice.

Table 10-46. Zéphine Debrief Responses

Liz	**Overall, how easy or difficult was it to figure out how to use the tool?**
Zéphine	The evaluation and the results was pretty straight forward. The ranking was not so straight forward. I was struggling.
Liz	**What parts of the tool were the most difficult and why?**
Zéphine	The ranking. The explanation and how you score the most important was not clear for me, maybe it was clear but I did not understand it.
Liz	**Which were the easiest and why?**
Zéphine	This evaluation, it was pretty straight forward and I liked that it had the capacity and willingness frozen there so I didn't have to go back to see what was capacity and what was willingness. And the description of each score was also clear.
Liz	**How do you perceive the amount of effort needed to use the tool?**
Zéphine	For the ranking, from 1 to 5 with 5 being the highest I can say 4. Maybe if you revise it, it could be easier to use.
Liz	**How do you perceive the overall usefulness of the tool?**
Zéphine	I think that it is really useful. I liked that I could see, especially in the results, I could just look at it and say "ok, this is the area I need to work on." That was really useful and I think organizations can really benefit from it.
Liz	**How do you perceive the amount of time needed to use the tool?**
Zéphine	Putting the ranking aside… it's not so time intensive. But the ranking, I think took a lot of time for me.
Liz	**If you used the tool for a future collaborative project, when during the project would you use it and how?**
Zéphine	During the project I would, so it has three phases so maybe before starting the project I would consider using it. And during the project I would use it to have an informational session and invite the developer to talk about the tool and how we can use it and what is the effect of using it to increase the contribution of people involved in the project.
Liz	**What recommendations would you offer an organization considering using the tool?**
Zéphine	I'm not sure because I've just used it once but, I think it also depends on what organization your talking about. But if it's an organization that is willing to collaborate with others. What I can tell is that, by looking at these results and these charts they can improve based on their experience from previous ones. Maybe they can use previous projects so they can know what areas they need to improve on and they can compare and see that maybe this is easier just by scoring the importance of practices and by evaluating their capacity and willingness they can easily figure out which areas they need to work on.
Liz	**What characteristics of an organization would they need in order to maximize the benefit out of using this tool?**
Zéphine	On organization that is involved in a collaborative project or maybe if it's just internal use, but you have different departments in the same organization that don't work everyday with each other but they can collaborate, they have separate boundaries, but they can collaborate. I think they could also benefit from using the tool. And university, we do a lot of interdisciplinary research so I think there would also be useful.

Liz	**What would you say is the most important thing that you learned from using the tool today?**
Zéphine	I think I never thought about marketing or the end user before now . So I think it's a good thing that I came across this tool. So I think now I can consider more the end user side of the project.